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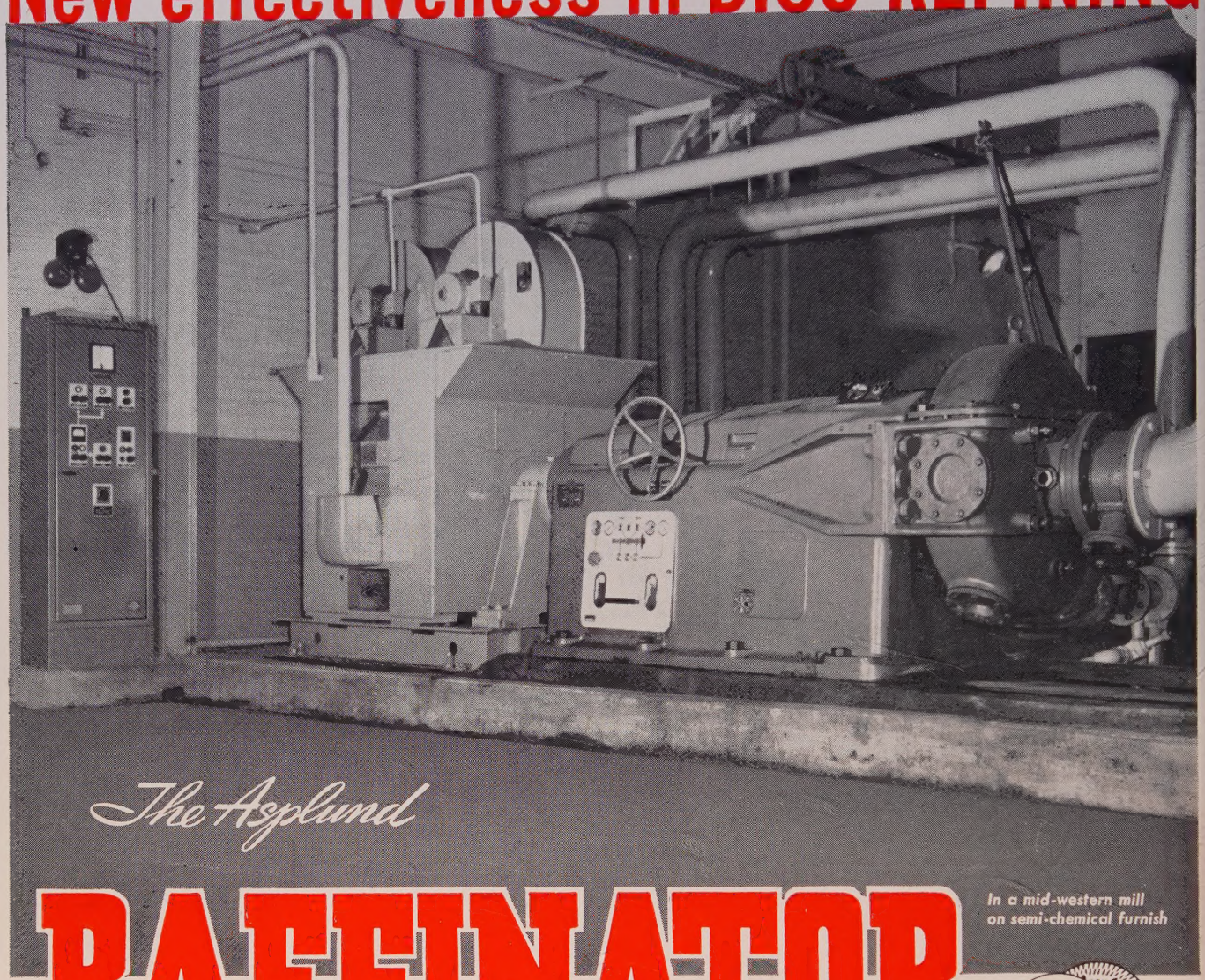
THE JOURNAL OF THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

MARCH 1961

VOLUME 44 • NUMBER 3

New effectiveness in DISC REFINING



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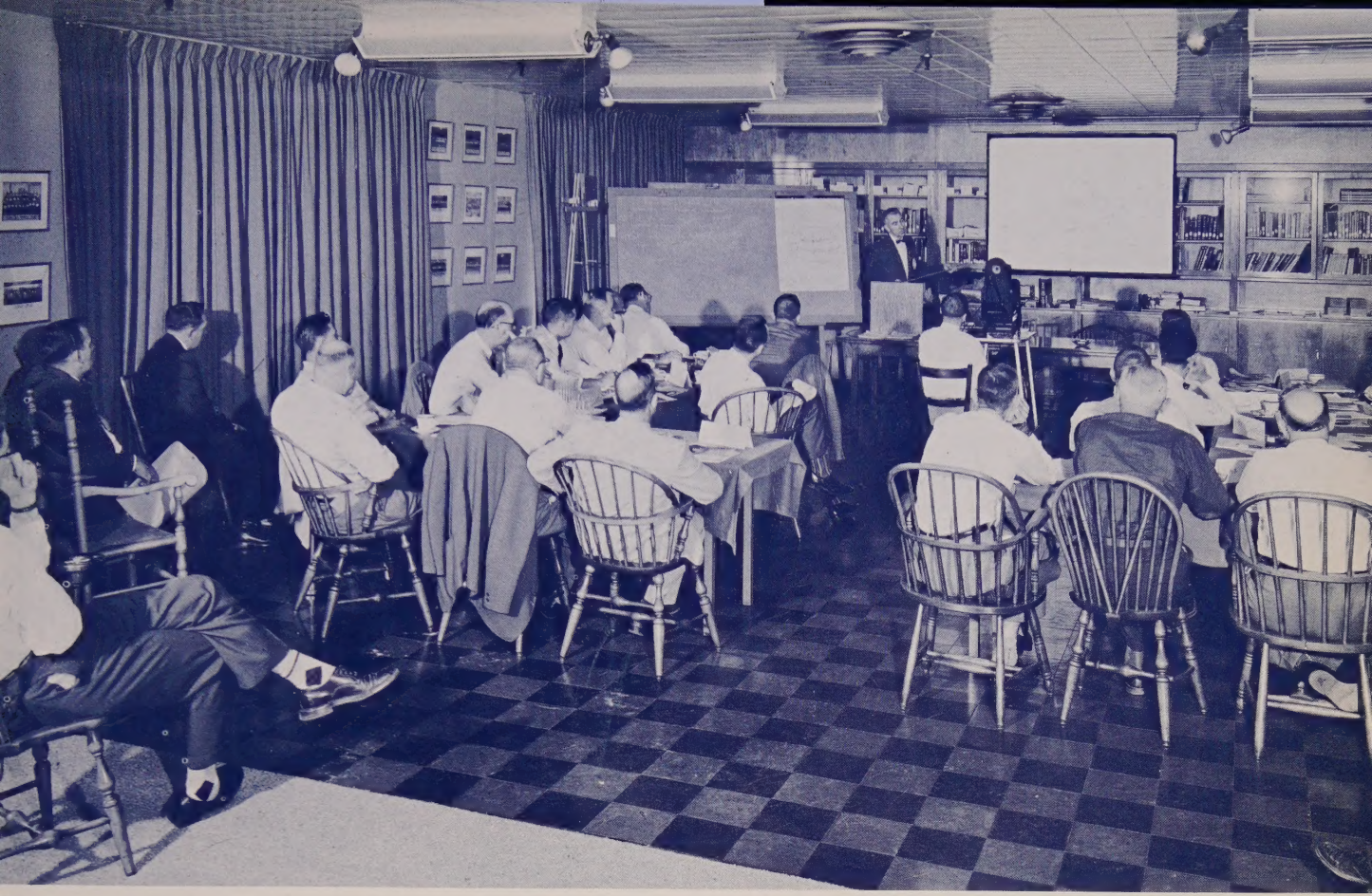

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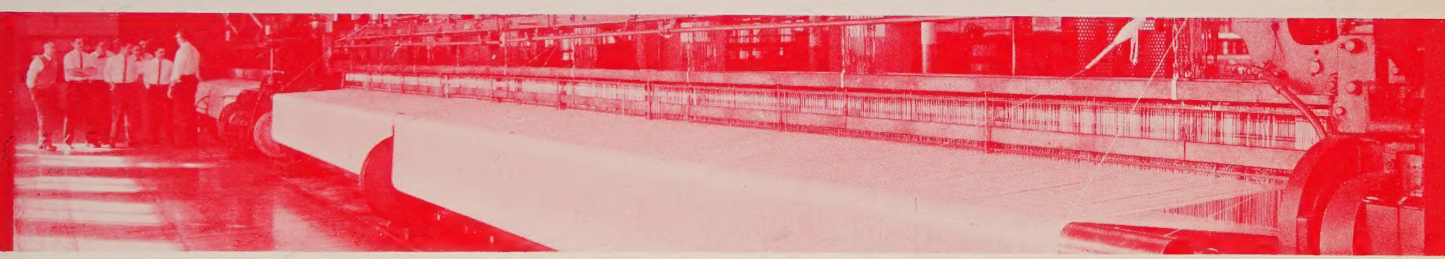

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III. June 21 - 23

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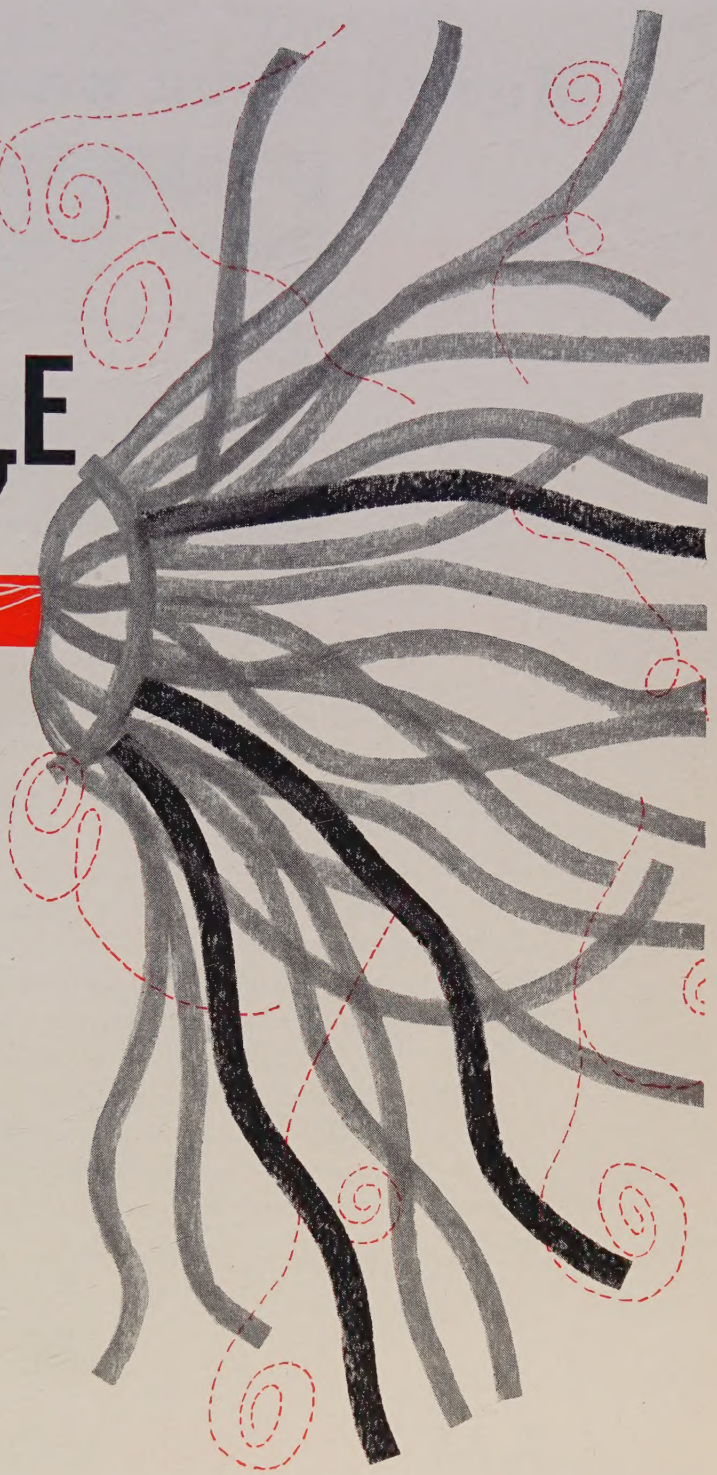

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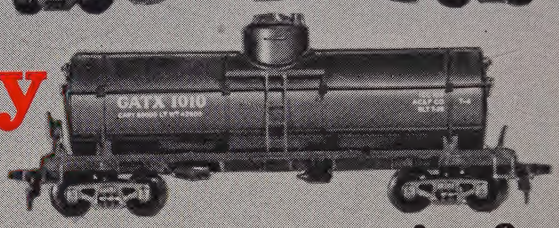

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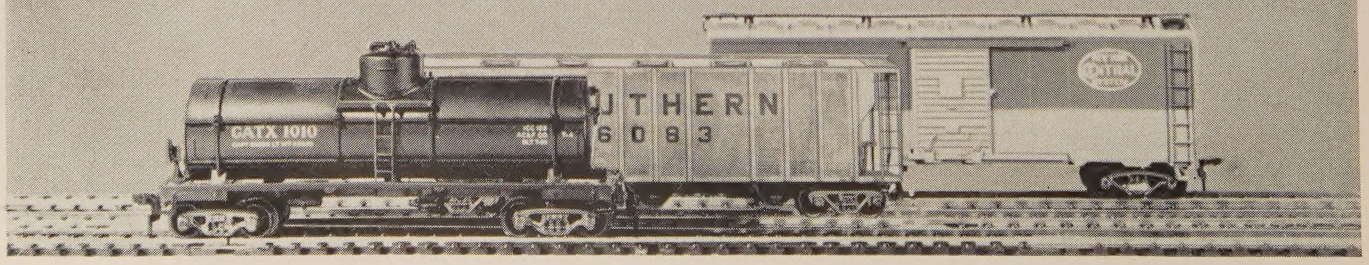

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May 8–10, 1961

Tenth Statistics Course
Queens Univ., Kingston, Ontario
June 17–30, 1961

Lignin Symposium
Edgewater Beach Hotel, Chicago, Ill.
Aug. 14–16, 1961

Twelfth Testing Conference
Queen Elizabeth Hotel, Montreal, Que.
Aug. 15–18, 1961

Eleventh Corrugated Containers Conference
St. Francis Hotel, San Francisco, Calif.
Sept. 6–8, 1961

Fourth International Mechanical Pulping Conference
(Tech. Sect., CPPA-TAPPI)
Edgewater Beach Hotel, Chicago, Ill.
Sept. 19–21, 1961

Sixth Deinking Conference
Hotel Harris, Kalamazoo, Mich.
Oct. 4–6, 1961

Sixteenth Plastics-Paper Conference
French Lick Sheraton Hotel,
French Lick, Ind.
Oct. 9–11, 1961

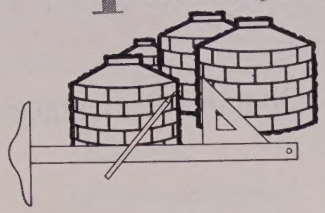
Sixteenth Engineering Conference
Shoreham Hotel, Washington, D. C.
Oct. 15–19, 1961

Fifteenth Alkaline Pul ing Conference
Rice Hotel Houston, Tex.
Nov. 1–3, 1961

Please refer to Local Section Activities for the locations and dates of Section Meetings

WEST END

advance planning



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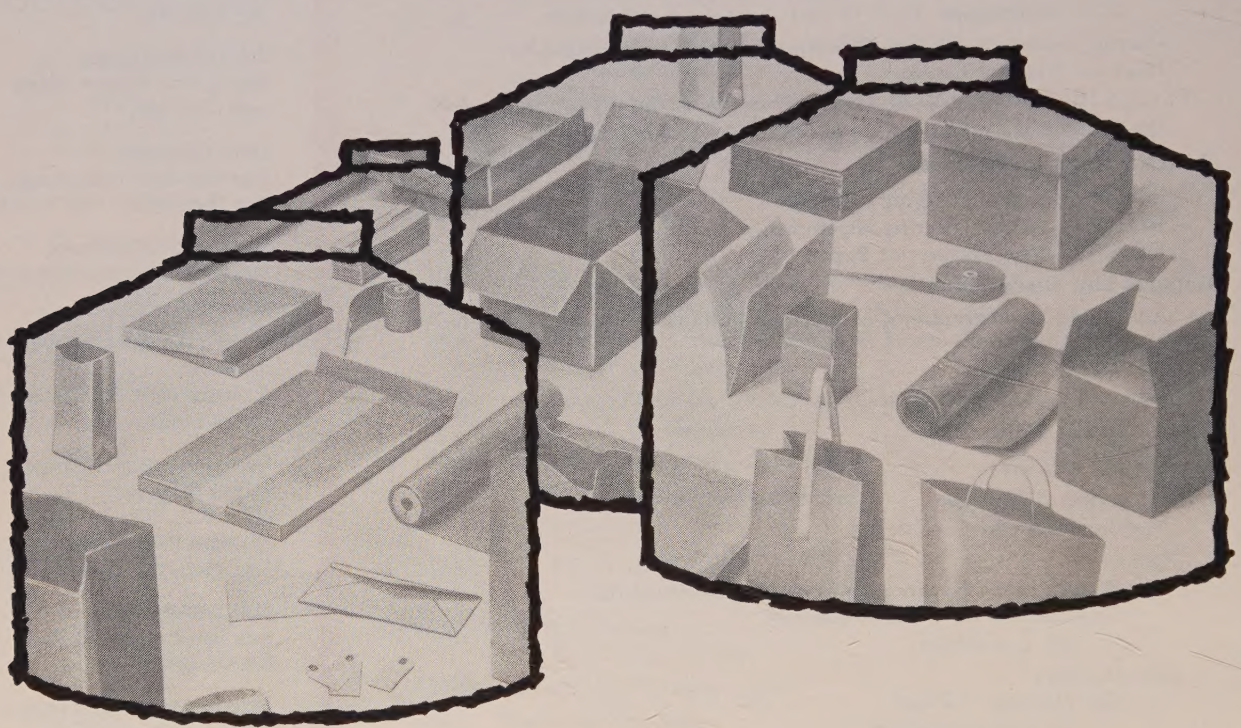

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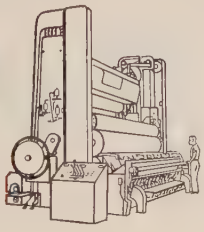

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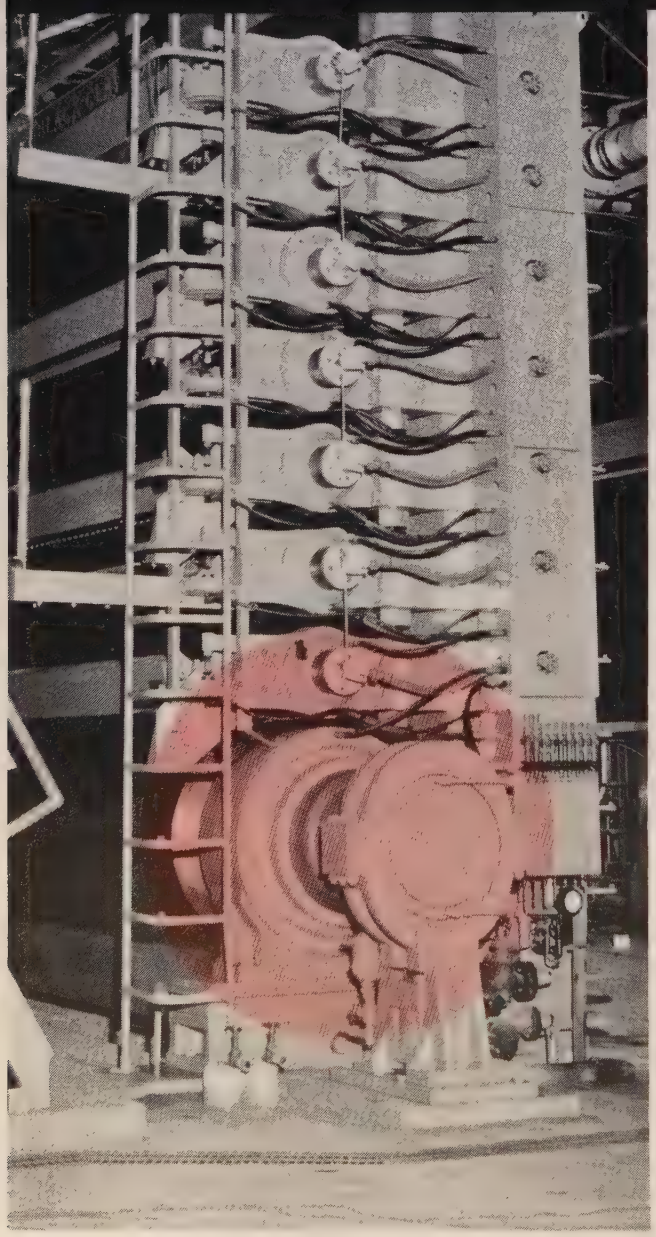

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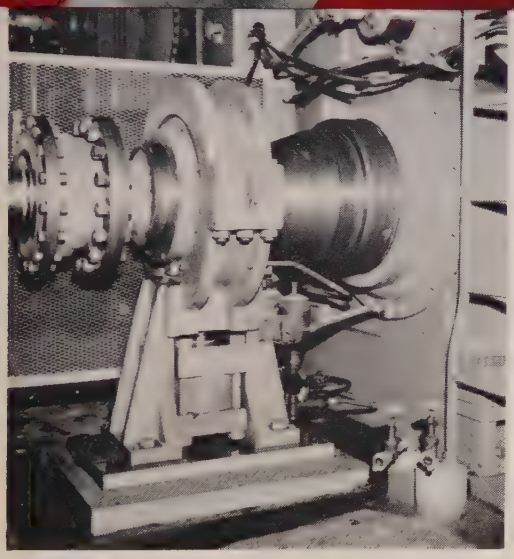
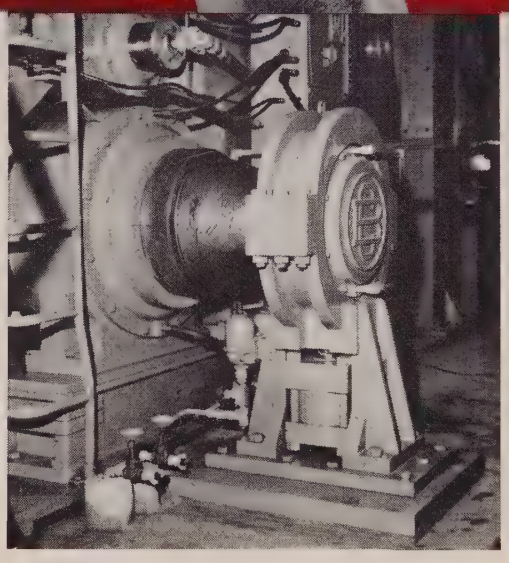


Drive side load cylinder and bearing



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Steam and Power

Papers presented at the Fifteenth Engineering Conference

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Water Treatment for High Makeup Boilers Operating in the Range of 600–1250 Lb.

LEONARD LIMON

Various types of water treatment equipment are reviewed and their application for high pressure boilers are discussed. Using different waters, each process is examined for several boiler pressures. This study includes equipment cost, installation cost, operating cost and other factors. In addition several examples are listed showing actual appilcations in the field. Problems encountered in the condensate cycle such as iron contamination are discussed. A possible answer to this problem is filtration, and different types of filters are composed. A new automatic method of monitoring very low concentrations of iron is described.

THE tendency of the last few years toward larger and higher pressure boilers continues. This is tied to many factors such as high power requirements, and the need for maximum economy in both initial investment and operating cost. Power engineers are realizing that high pressures may mean more expensive water treating equipment and that all plant studies must include these costs. This paper will discuss various aspects of equipment required for different boiler pressures and different waters. In addition, condensate treatment, which has been neglected, is now becoming of primary importance and will be considered.

QUALITY OF WATER REQUIRED

In order to have some standards, we have set down some recommended approximate values of key constituents in makeup water as follows:

Boiler pressures	*600 p.s.i.g.*	*900 p.s.i.g.*	*1250 p.s.i.g.*
Alkalinity	Less than 25 p.p.m.	Less than 25 p.p.m.	Less than 5 p.p.m.
Silica	2–4 p.p.m.	1 p.p.m.	Less than 0.1 p.p.m.
Total dissolved solids	100	Less than 25	Less than 5
Hardness	0–2	0–1	0–1
Dissolved oxygen	0.005	0.005	0.005

These are optimum values and can vary somewhat. The tendency is, of course, always to aim toward the safe side.

TYPES OF WATER TREATMENT

There are four basic types of external water treating equipment available to give the types of makeup water required. These are basically as follows.

Sodium Zeolite or Sodium Hydrogen Zeolite Softening

This type of treatment consists of passing the water through an ion exchange material regenerated with sodium chloride. It is also possible to regenerate a unit with sulfuric acid, passing part of the water through the sodium zeolite and part through the hydrogen zeolite and then to a degasifier. This results not only in low hardness but reduces the alkalinity and consequently the total solids. This treatment in the sodium cycle reduces hardness only, having no other effect on the water. There is no effect on the silica. Therefore, this treatment would be applicable in the 600 lb. range only for relatively low solids, low silica water or water with relatively high alkalinity, but low silica. This type of treatment also might be tied into a cold process unit which could reduce hardness, alkalinity, and silica followed by sodium zeolite. The basic sodium zeolite unit, while it is the least expensive, has a very narrow range of use in this boiler pressure and therefore it could only be considered in a few special cases.

LEONARD LIMON, Graver Water Conditioning Co., New York, N. Y.

Desilicizer—Silica Removal by Anion Exchange

This process gives a relatively new tool for medium pressure boilers using makeup that is relatively low in solids and alkalinity. In this process the water first passes through a sodium zeolite unit and then through a strongly basic anion unit regenerated with caustic. The water is softened, silica is reduced, and all anions are changed to the hydroxide form. Therefore, it is necessary to follow this plant with an acid feed, possibly sulfuric or phosphoric acid. With some waters this would give low silica and where the high quality of demineralized water is not in the boiler ranges below 900 lb. this might be preferable to hot process water softening.

Hot Process—Hot Zeolite Softening

In this process the water is first heated and lime-softened in the hot process pressure vessel and is then filtered and passed through sodium zeolite softeners. This process is applicable up to boiler pressures of about 900 to 1000 lb. It has the great advantage of reducing silica to less than 1 p.p.m. With calcium and magnesium alkalinity waters the alkalinity and total solids can be reduced and the use of hot zeolite gives a zero hardness water. For many medium range plants the hot process softener if properly designed can give an excellent water. Hot process has the further advantage that whereas any one of the ion exchange processes needs good pretreatment if a river water is used, the hot process can handle relatively high turbidities. It has the disadvantage of being more subject to changes in water analysis and to some extent rapidly surging loads. All these factors should be taken into consideration.

Demineralization

In this process the water is passed through a hydrogen regenerated cation exchanger and through a caustic regenerated anion exchanger. This results in a water with very low total solids, low silica—in fact, the ultimate water for plants in the 600 to 1250 lb. pressure range. There are many variations of the demineralizing plant such as the use of degasifiers and/or vacuum deaerators and the use of weak base as well as strong base anion exchangers. In the pressure range above 1000 p.s.i.g. this represents the best method of obtaining the quality of makeup water needed. In many cases and on a great many waters it can be justified in pressure ranges as low as 600 p.s.i.g. It thus has the ability to compete with any of the other processes regardless of pressure range, but generally must be used in pressure ranges above 1000 lb. It is usually the most expensive process from the point of view

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Table I. Typical Low Solids Water

Constituent	P.p.m. as:	I Influent water	II After Na_2Z	III After Na_2Z desilicizer acid	IV After hot process—hot zeolite	V After demineralizer
Cations						
Calcium (Ca^{++})	$CaCO_3$	20	0–1	0–1	0–1	...
Magnesium (Mg^{++})	$CaCO_3$	10	0–1	0–1	0–1	...
Sodium (Na^{+})	$CaCO_3$	20	48	48	45	...
Hydrogen (H^{+})	$CaCO_3$	...	...	...	...	...
Total cations	$CaCO_3$	50	50	50	47	0–1
Anions						
Bicarbonate (HCO_3^{-})	$CaCO_3$	25	25	0	0	...
Carbonate (CO_3^{--})	$CaCO_3$	...	...	...	25	...
Hydroxide (OH^{-})	$CaCO_3$	...	...	10	0	...
Sulfate (SO_4^{--})	$CaCO_3$	15	15	39	13	...
Chloride (Cl^{-})	$CaCO_3$	10	10	1	9	...
Total anions	$CaCO_3$	50	50	50	47	0–1
Total hardness	$CaCO_3$	30	0–2	0–2	0–2	0–1
Methyl orange alkalinity	$CaCO_3$	25	25	10	25	0–1
Iron, total	Fe	...	...	...	...	...
Carbon dioxide, free	CO_2	...	...	...	...	...
Silica	SiO_2	7–10	7–10	<1	<1	0.05
Turbidity	...	...	...	...	...	...
Color	...	...	...	...	...	...
pH	...	...	...	...	...	...

of initial investment and operating cost and therefore must be fully evaluated. In many cases, such an evaluation would indicate operating factors or other reasons that demineralizing can be used. Often, however, an incomplete evaluation does not take into account the extra cost of pretreatment for the demineralizer, and therefore shows demineralizing as being less expensive than it really is. There is no substitute for a complete evaluation of all the factors involved.

Design Criteria

The following considerations must be taken into account in any complete evaluation:

1. Operating chemical cost.
2. Operating labor cost.
3. Equipment cost.
4. Installation cost.
5. Blowdown.
6. Boiler outages.
7. Turbine cleaning.
8. Space requirements.

Instrumentation can vary widely depending on the degree of automation required. This can have a serious effect on the type of equipment chosen because of its influence on the initial investment.

TYPICAL PLANTS

Low Solids Water

Table I gives figures on a low solids water of the type found in some sections of the southeast and northwest. Typical analyses are shown after each of the four processes discussed above. Table II indicates the approximate equipment cost and approximate chemical operating cost.

Let us examine this water in relation to three boiler pressures, 600, 900, and 1250 p.s.i.g. The use of sodium zeolite would only be applicable to a water of this type assuming the silica were substantially lower, in the range of 2 to 4 p.p.m. Therefore, there need be no further discussion of this process.

Hot process, as is usually the case, gives the lowest operating cost. The desilicizer and the demineralizer are substantially higher, at about the same level. Equipment cost installed is about the same for hot process and the desilicizer. The most expensive system is the demineralizer.

For a 600-lb. boiler, it would be a fairly difficult choice. Hot lime zeolite has the lowest operating cost and about the same equipment cost as the desilicizer. It is more sensitive to load variations but is still a simple process. The desilicizer will give lower carbon dioxide in the steam but involves handling caustic and acid. Space may or may not be a problem. The anion resin is also more sensitive than the cation resin acid in the hot zeolite. Personal preference would have a great deal to do in this case. Demineralizing would be more difficult to justify at this boiler pressure.

An important consideration would be the source of the water, and whether there were any organic matter or turbidity

Table II. Comparison Equipment Costs and Operating Costs—Low Solids Water

Makeup—350,000 lb./hr. Pretreatment not included

	Cents/1000 gal.	Yearly cost based 75% load factors, $
Operating Costs—Chemicals		
Sodium zeolite	0.7	1,920
Sodium zeolite desilicizer acid	8.2	22,500
Hot lime zeolite	2.7	7,400
Demineralizer	7.5	20,500

	Equipment costs, $	Erection (no building), $	Total, $
Equipment			
Sodium zeolite	30,000	7,500	37,500
Sodium zeolite, desilicizer acid	85,000	30,000	115,000
Hot lime zeolite	72,000	45,000	117,000
Demineralizer	115,000	55,000	170,000

Table III. Typical Medium Solids Water

Constituent	P.p.m. as	I Influent water	II After hot process—hot zeolite	III After demineralizing
Cations				
Calcium (Ca^{++})	$CaCO_3$	75	0–1	...
Magnesium (Mg^{++})	$CaCO_3$	30	0–1	...
Sodium (Na^{+})	$CaCO_3$	50	75	...
Hydrogen (H^{+})	$CaCO_3$	..	..	...
Total cations	$CaCO_3$	155	77	0–2
Anions				
Bicarbonate (HCO_3^{-})	$CaCO_3$	100	0	...
Carbonate (CO_3^{--})	$CaCO_3$	..	25	...
Hydroxide (OH^{-})	$CaCO_3$	..	5	...
Sulfate (SO_4^{--})	$CaCO_3$	40	34	...
Chloride (Cl^{-})	$CaCO_3$	15	13	...
Total anions	$CaCO_3$	155	77	0–2
Total hardness	$CaCO_3$	105	0–2	0–1
Methyl orange alkalinity	$CaCO_3$	100	30	0–1
Iron, total	Fe	..	..	...
Carbon dioxide, free	CO_2	..	..	...
Silica	SiO_2	8	<1	<0.05
Turbidity	...	..	..	...
Color	...	..	..	...
pH	...	..	..	...

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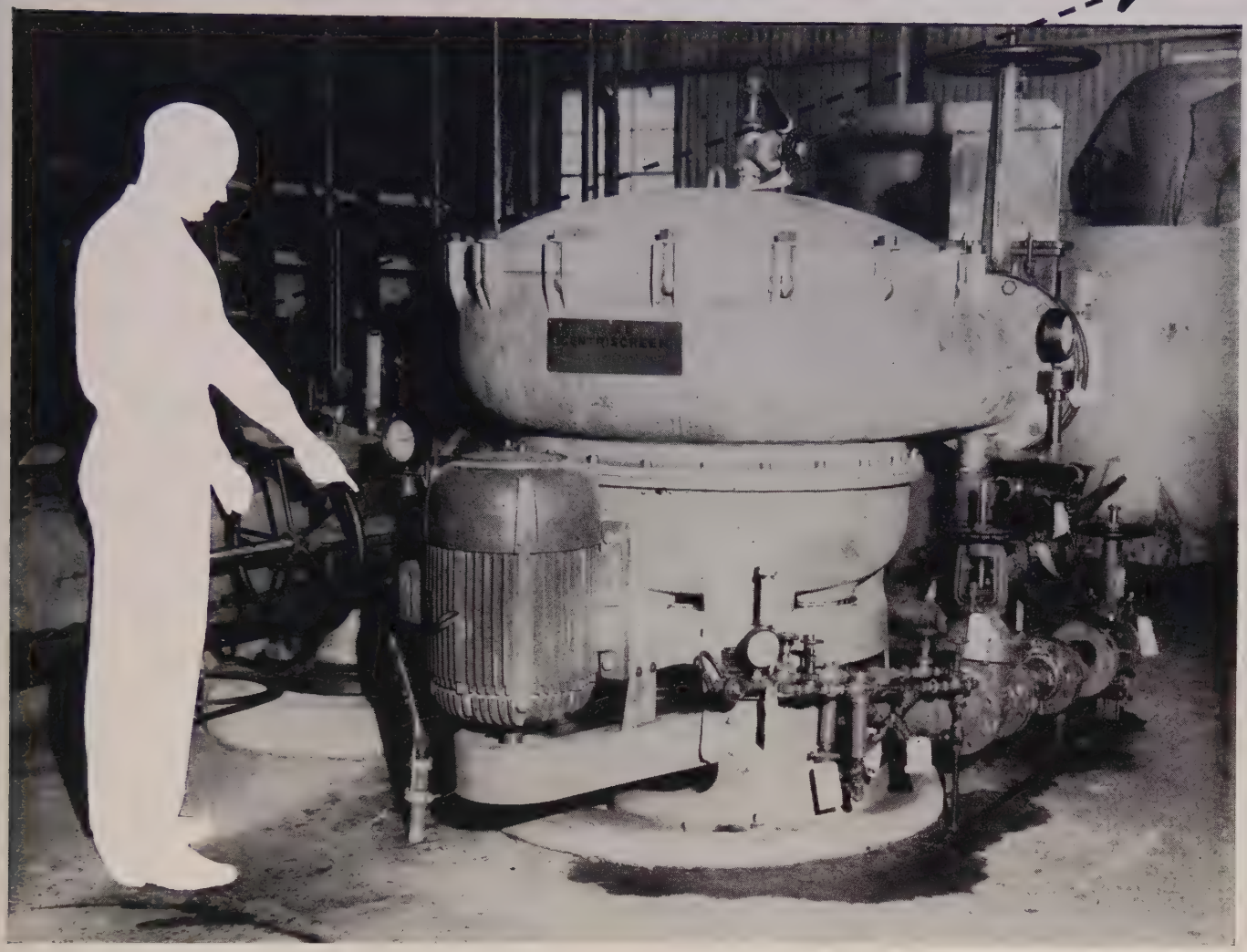

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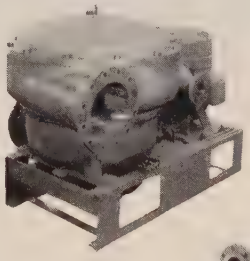

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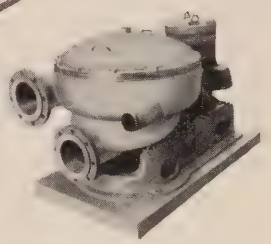

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Table IV. Comparison Equipment Costs and Operating Costs—Medium Solids Water

Makeup—350,000 lb./hr. Pretreatment not included

	Cents/1000 gal.	*Yearly cost based 75% load factors, $*
Operating Costs—Chemicals		
Hot lime zeolite	3.1	8,500
Demineralizer	10.0	27,500

	Equipment costs, $	*Erection (no building), $*	*Total, $*
Equipment			
Hot lime zeolite	72,500	45,000	117,500
Demineralizer	125,000	57,000	182,000

present. For example, if this water were to come from a river it would have to be pretreated before the desilicizer or the demineralizer, but possibly not before the hot process. However, in many paper mills pretreatment is required for plant service water, and if this equipment is being installed anyway there would be little or no charge against the boiler feedwater plant.

If pretreatment of a river water were required, consisting of coagulation and filters, the cost of desilicizer equipment would go up at least 50% and then hot process equipment would be much more seriously considered and probably used. For a 900-p.s.i.g. boiler the same general considerations would apply. In this case, all three of the processes would still give the amount of silica required although there are many who believe that at 900 p.s.i.g. the lowest possible silica is recommended. This could only be obtained by demineralization.

For the 1250-p.s.i.g. plant and above, demineralization would definitely be used. This is necessary since it is the only method that would give the low solids and low silica required to avoid problems. Pretreatment might or might not be necessary but it is felt that there is no alternative in this case to demineralizing.

Medium Solids Waters

Table III shows a typical medium solids water that is encountered in many parts of this country. Sodium zeolite treatment or sodium and desilicizing are immediately eliminated because only the solids and silica are too high; second, desilicizing would prove expensive from the point of view of both operating cost and initial investment. In the large size

Table V. Typical Higher Solids Water

Constituent	*P.p.m. as:*	*I Influent water*	*II After hot process–hot zeolite*	*III After demineralizing*
Cations				
Calcium (Ca^{++})	$CaCO_3$	250	0–1	...
Magnesium (Mg^{++})	$CaCO_3$	125	0–1	..
Sodium (Na^{+})	$CaCO_3$	100	180	..
Hydrogen (H^{+})	$CaCO_3$	..	..	...
Total cations	$CaCO_3$	475	182	0–3
Anions				
Bicarbonate (HCO_3^{-})	$CaCO_3$	275	0	
Carbonate (CO_3^{--})	$CaCO_3$	..	25	...
Hydroxide (OH^{-})	$CaCO_3$	..	5	...
Sulfate (SO_4^{--})	$CaCO_3$	90	77	...
Chloride (Cl^{-})	$CaCO_3$	110	95	...
Total anions	$CaCO_3$	475	182	0–3
Total hardness	$CaCO_3$	375	0–2	...
Methyl orange alkalinity	$CaCO_3$	275	30	...
Iron, total	Fe	..	..	...
Carbon dioxide, free	CO_2	..	..	...
Silica	SiO_2	15	<1	<0.05
Turbidity	...	..	..	...
Color	...	..	..	...
pH	...	..	..	...

Table VI. Comparison Equipment Costs and Operating Costs—Higher Solids Water

Makeup—350,000 lb./hr. Pretreatment not included

	Cents/1000 gal.	*Yearly cost based 75% load factor, $*
Operating Costs—Chemicals		
Hot lime zeolite	4.1	11,200
Demineralizer	34.0	94,000

	Equipment costs, $	*Erection (no building), $*	*Total, $*
Equipment			
Hot lime zeolite	75,000	45,000	120,000
Demineralizer	257,000	95,000	352,000

plants under consideration in paper mills it would not be practical. The best processes therefore would be hot process–hot zeolite and demineralization.

As far as operating cost and equipment cost, hot process–hot zeolite is substantially less expensive for this type of water. It again has the advantage of requiring simpler pretreatment. Therefore, for the 600-p.s.i.g. boiler, hot process would definitely be preferred. For the 900-p.s.i.g. boiler, it would also, in the majority of cases, be used with the exception of those cases which require or want lower silica. Above the 900-p.s.i.g. range a demineralizer would be used. Table IV indicates the operating cost and equipment cost for the two processes.

Higher Solids Water

For higher solid waters in the range of 200 p.p.m. and above the same general conclusions apply as to the medium solids water. Generally the hot process plant becomes more attractive from the point of view of both equipment cost and initial investment with the increase in solids.

Table V indicates a higher solids water and Table VI shows equipment cost and operating cost for the hot process–hot zeolite plant and the demineralizer plant. This clearly indicates the advantages of the hot process type system up to and including the 900-p.s.i.g. boiler. Above this pressure the

Table VII

Constituent	*P.p.m. as:*	*I Raw water—after pretreatment and filtration*	*II After demineralizer*
Cations			
Calcium (Ca^{++})	$CaCO_3$	25	...
Magnesium (Mg^{++})	$CaCO_3$	4	..
Sodium (Na^{+})	$CaCO_3$	16	...
Hydrogen (H^{+})	$CaCO_3$	..	...
Total Cations	$CaCO_3$	45	1–2
Anions			
Bicarbonate (HCO_3^{-})	$CaCO_3$	21	...
Carbonate (CO_3^{--})	$CaCO_3$	..	...
Hydroxide (OH^{-})	$CaCO_3$	..	...
Sulfate (SO_4^{--})	$CaCO_3$	6	...
Chloride (Cl^{-})	$CaCO_3$	18	...
Total anions	$CaCO_3$	45	1–2
Total hardness	$CaCO_3$	29	0–1
Methyl orange alkalinity	$CaCO_3$	21	0–1
Iron, total	Fe	..	...
Carbon dioxide, free	CO_2	..	...
Silica	SiO_2	11	0.02
Turbidity	...	..	...
Color	...	..	...
pH	...	..	...

Chemical Operating Cost

Chemical	*Dosage, lb./1000 gal.*	*Cost, ¢/lb.*	*Cost, ¢/1000 gal.*
Sulfuric acid, 66° Bé	1	1.5	1.5
Caustic, 100% NaOH	1.4	4.0	5.6
			7.1

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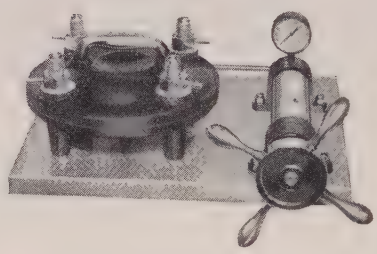

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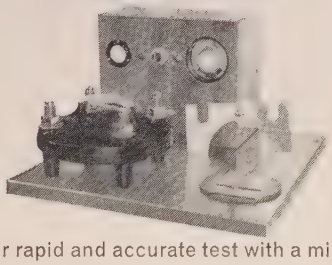

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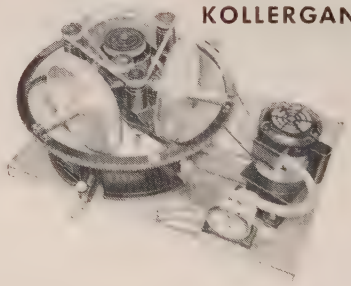

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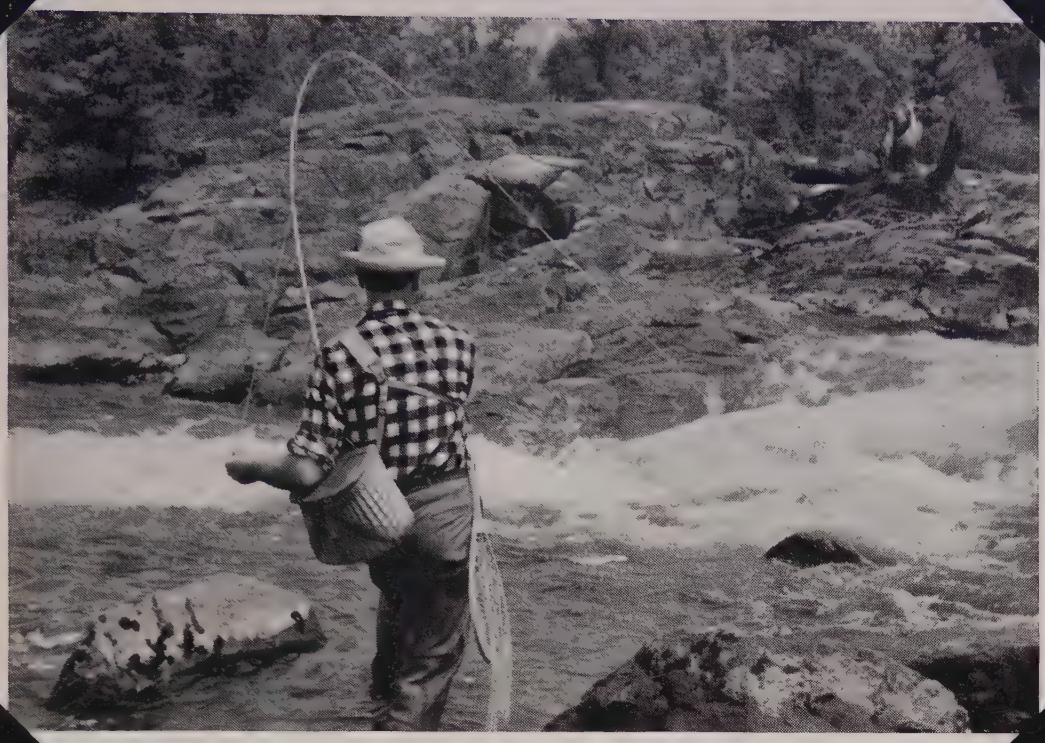

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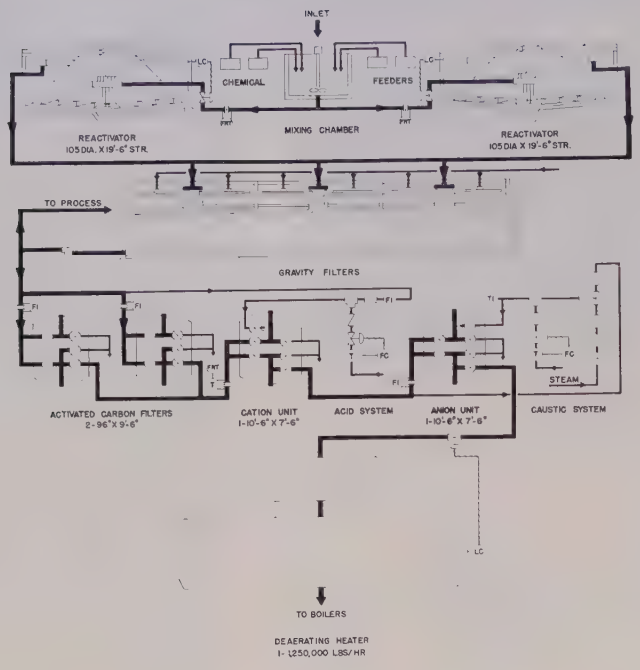


SOUTHERN MILL

Fig. 1

demineralizer would generally be used since it produces the best water.

ACTUAL PLANTS

Large Southern Mill

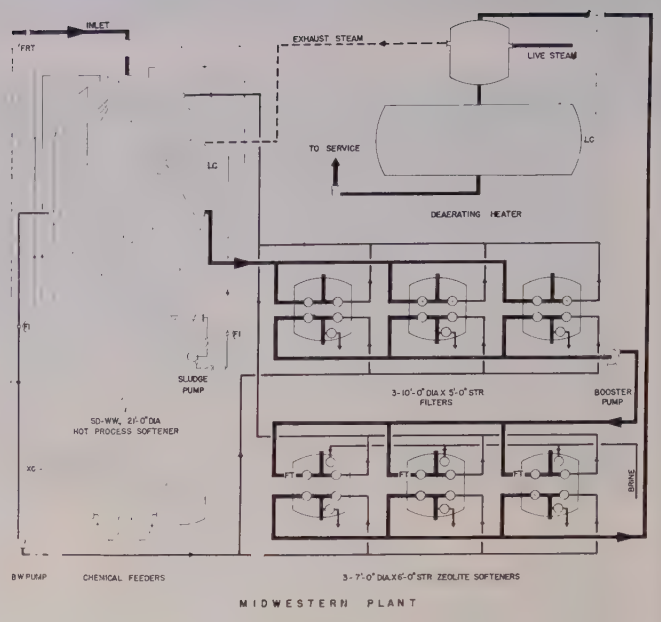
At this mill, design boiler pressure is 875 p.s.i.g. and power is to be generated. Table VII shows the water used. Based on previous comments, it is apparent that hot process is not applicable. This plant is installing a large pretreatment plant for process water and therefore the cost of pretreatment is no

Table VIII

Constituent	*P.p.m. as:*	*I Influent water*	*II After hot process—hot zeolite*	*III After demineralizing*
Cations				
Calcium (Ca^{++})	$CaCO_3$	84	0–1	1
Magnesium (Mg^{++})	$CaCO_3$	46	0–1	1
Sodium (Na^{+})	$CaCO_3$	4	72	2
Hydrogen (H^{+})	$CaCO_3$	...	...	...
Total cations	$CaCO_3$	134	74	0–4
Anions				
Bicarbonate (HCO_3^{-})	$CaCO_3$	90	0	...
Carbonate (CO_3^{--})	$CaCO_3$	...	25	...
Hydroxide (OH^{-})	$CaCO_3$	...	5	1
Sulfate (SO_4^{--})	$CaCO_3$	33	33	2
Chloride (Cl^{-})	$CaCO_3$	11	11	1
Total anions	$CaCO_3$	134	74	0–4
Total hardness	$CaCO_3$	130	0–2	0–2
Methyl orange alkalinity	$CaCO_3$	...	...	...
Iron, total	Fe	...	...	...
Carbon dioxide, free	CO_2	...	...	...
Silica	SiO_2	3–6	1	0.05
Turbidity	...	...	...	...
Color	...	...	...	...
pH	...	7.3	10.2	7.5

Chemical Operating Cost

Chemical	*Dosage, lb./1000 gal.*	*Cost ¢/lb.*	*Cost ¢/1000 gal.*
Hot process			
Dolomitic lime, 62%	1.4	1	1.4
Salt	1.0	1.0	1.0
			2.4
Demineralizing			
Sulfuric acid, 66° Bé	3.2	1.5	4.8
Caustic soda, 100%	1.3	3.5	4.6
			9.4



MIDWESTERN PLANT

Fig. 2

factor. It was felt that at this boiler pressure demineralization was the best process and would give the lowest total dissolved solids and the low silica needed.

Figure 1 is the flow diagram and indicates the equipment furnished. The main process water is coagulated in two 105 ft. 0 in. diam. Reactivators® and filtered in gravity units. A small portion of the flow then goes to the boiler feed plant, about 350,000 lb. per hr. The water is treated in two activated carbon filters and then goes to one 10 ft. 6 in. diam. cation unit and one 10 ft. 6 in. diam. anion unit. This plant is designed for pushbutton automatic operating using air-operated Saunders Patent valves actuated by a cycle controller.

Caustic and acid for regeneration are fed directly under pressure and are controlled and diluted by automatic in-line instruments. Since there is one cation and one anion, storage of demineralized water is provided to allow for regeneration time. All components in the plant have been designed for maximum reliability since there is no spare equipment. Future expansion would involve the addition of one cation unit and one anion unit. Flow from the demineralizer is to a tray deaerator with a stainless steel internal vent condenser. All plants of this type require full deaeration.

Midwestern Plant

At this large plant, a careful design study was made to determine the most economical boiler pressure and turbine pressure.

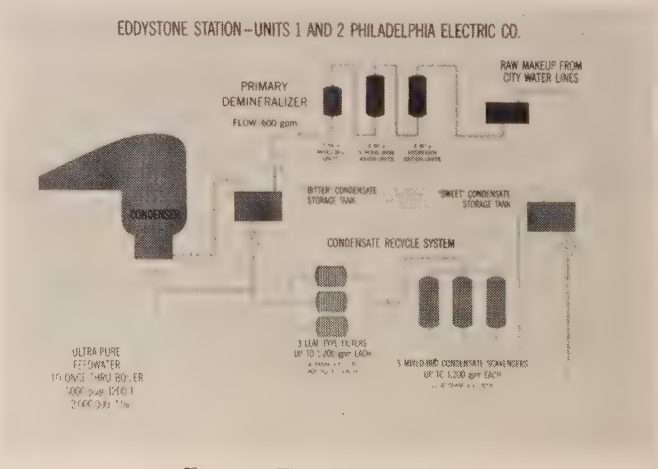
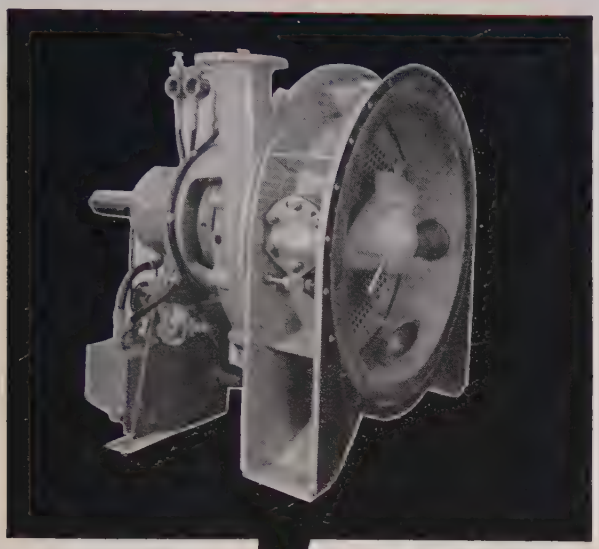
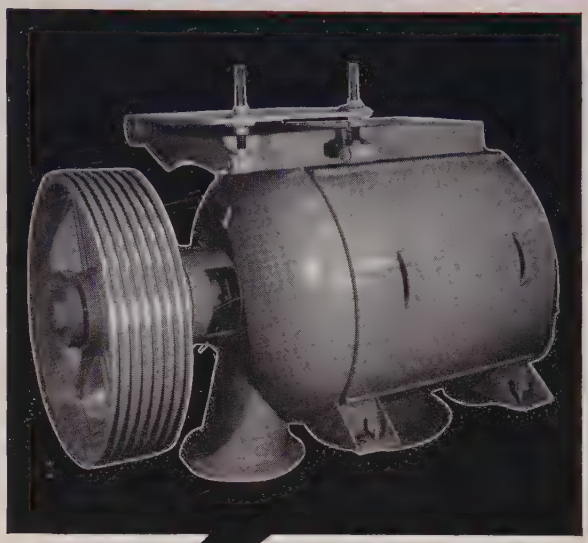
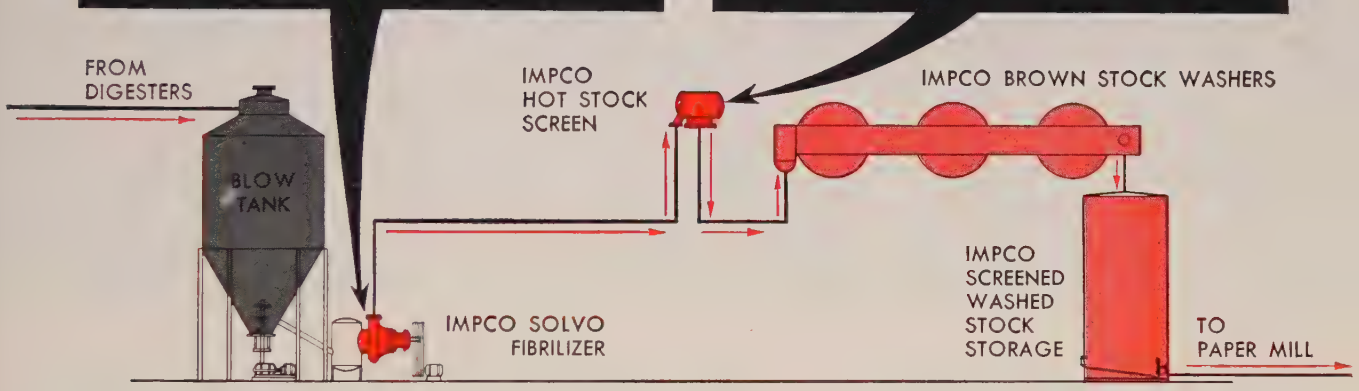


Fig. 3. Eddystone station

Impco *Again* Simplifies the Pulping Process with the Fibrilizer and Hot Stock Screen







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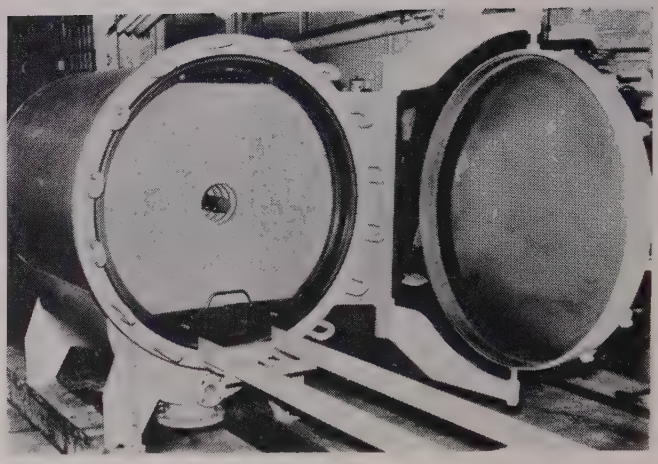

Fig. 5. Graver-Davis filter

Pressures of 950 and 1250 p.s.i.g. were considered. Water analysis is shown in Table VIII. It was felt that for 950 p.s.i.g. either hot process or demineralizing could be used. For 1250 p.s.i.g. demineralizing would be required. As shown in Table VIII the difference in operating cost is substantial, 5¢ per 1000 gal.

Based on the plant makeup of 350,000 lb. per hr. 75% load factor, this difference amounts to $13,750 per year. Approximate cost of the hot process hot zeolite plant installed is $185,000. Approximate cost of demineralization installed is $275,000. On this basis it was decided that the extra efficiency of the 1250-p.s.i.g. plant could not be justified. Design pressure was set at 950 p.s.i.g. using hot process–hot zeolite makeup equipment. In this case, the equipment cost and operating cost of the water treating equipment was an important part of the overall evaluation in selecting plant design pressures.

Since this hot process plant is treating water for a fairly high pressure boiler, careful selection of equipment was required. Figure 2 shows the flow diagram of this plant. In order to obtain lower silica a sludge blanket unit is used. The hot process tank is designed with a clean and dirty water compartment. This avoids any shocks in the system during backwashing. Also, the filters and zeolites are always backwashed with filtered water. The resin used in the ion exchange units is of the 10% cross-linked, white resin type to avoid any problems of degradation. In addition, deaeration of makeup is included in the hot process tank to protect the resin. A separate large deaerator is included. Overall, this will give a relatively simple and foolproof type plant.

Fig. 4. Comparisons of Filter Design

Filter Design	*Media Used*	*Advantages*	*Disadvantages*
Replaceable Cartridge	Cotton, fabric or other, wound	Minimum space requirements Moderate area flow rates Long life when crud level is low Low initial cost No backwash water required	High replacement costs when crud level high Filter maintenance high if crud level high
Sintered Metal	Sintered stainless steel	Minimum space requirements Moderate area flow rates Long life when crud level is low No backwash water required Good for high temperature operation	Poor clogging resistance High initial cost High maintenance costs Short life when crud level is high
Precoat a) Tubular Element	Cellulose	Moderate backwash water required Moderate area flow rates Excellent clogging resistance Low operating costs Low pressure drops Flexibility in operation with varying crud levels	Periodic maintenance Moderate space requirements Internals not easily accessible
b) Leaf Element	Cellulose	Same as 1–6 above plus Easy accessibility for inspection of internals Easily modified to meet service requirements	Moderate quantity backwash water required Periodic maintenance
Granular Bed	Ion exchange resin Magnetic iron oxide Activated Carbon	Excellent particle retention Higher operating temperatures and pressures High area flow rates Reuseable filter media	Condensate backwash water required High head loss Higher space requirements Periodic cleaning or replacement of media

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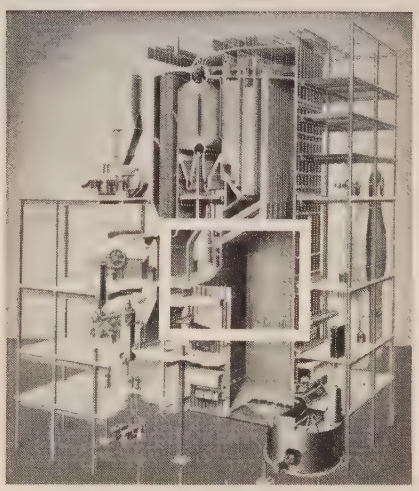

The C-E Recovery Unit. Section of illustration has been enlarged to show the upward-spiralling gas path produced by C-E's exclusive *tangential* introduction of secondary air. Inset (above, left): diagram of tangent principle.

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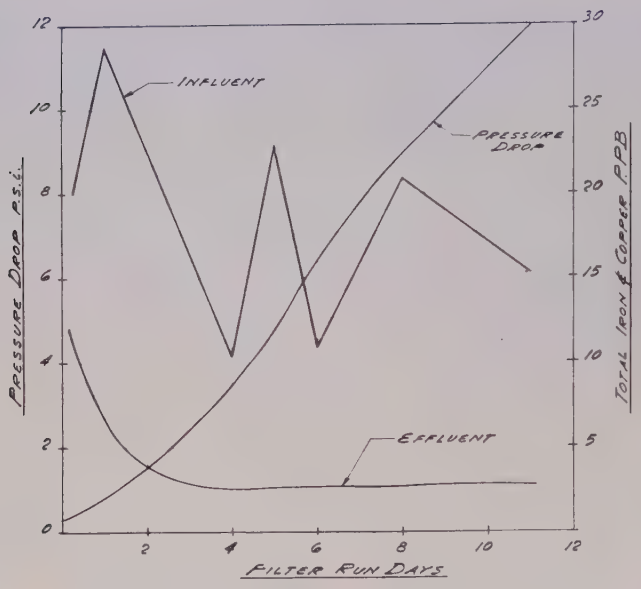

Fig. 6

NEW TREATMENT AND TESTING METHODS

While a complete study is made of the makeup cycle there is often too little attention given to the condensate cycle. The flow of water in the condensate system is equal to or in many cases more than the makeup system. In many plants, serious problems in the condensate lines and also boiler tube failures have occurred from high iron or copper entering the system through condensate corrosion. This may be due to carry-over of carbon dioxide into the condensate system or leakage of oxygen in the system at various points.

Iron as high as 100 to 150 p.p.b. has been found in many systems; boiler problems such as tube failures have been attributed to this. In some cases, this can be controlled quite successfully by filming amines. This may be expensive and while it can help solve the problem, filtration should also be examined as a possible solution. In many cases, filtration and the feeding of various chemicals will be required.

For further background, brief mention should be made of some of the work being done in the central station field. These plants are operated at very high pressure and the problems encountered are therefore enlarged. Further, the use of the once-through boiler has required extremely pure water. The engineers in the power field have had to face the fact that treating makeup only is not the complete answer

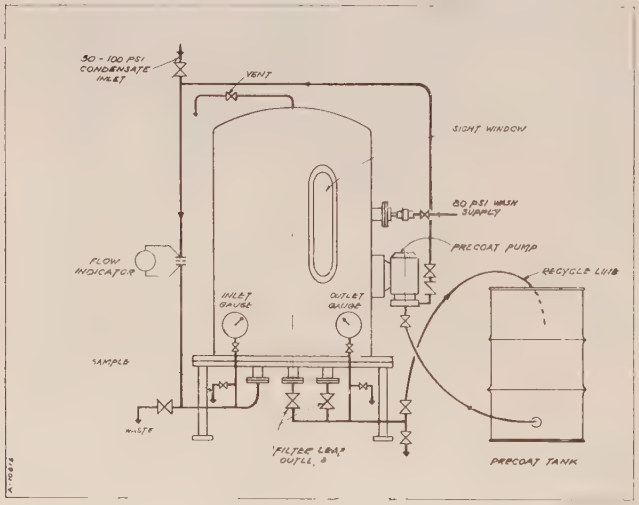

Fig. 7. Filter pilot plants

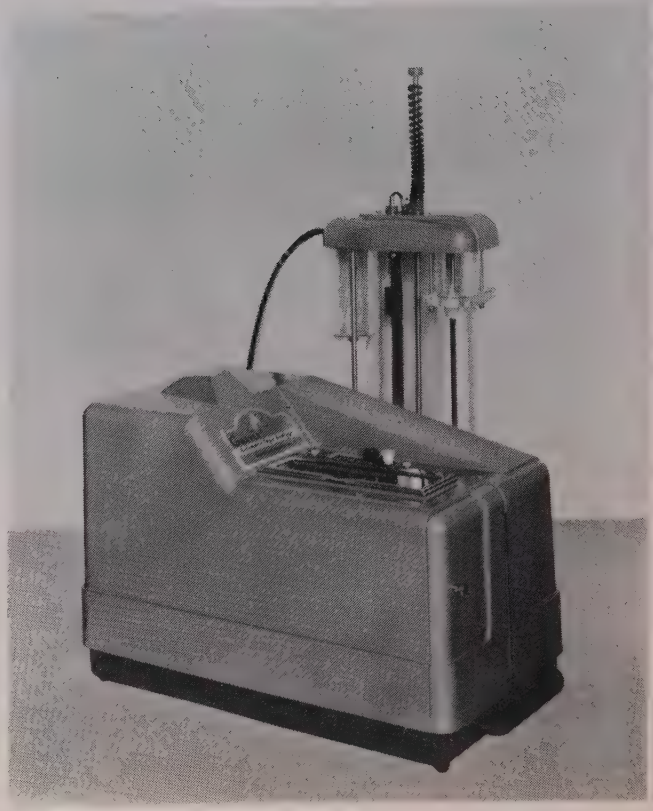

Fig. 8. Graver automatic tape analyzer

since condensate may be 99% of the flow. Therefore, even relatively small pickups of contamination in the condensate can represent a fairly large amount of contaminant. The problem in the central station is further complicated by the requirements of cleaning up the system during startup. Figure 3 shows a flow diagram of the condensate system used Eddystone Station. This is very elaborate since the condensate is not only filtered but also demineralized. Obviously, the use of demineralizers on condensate would not be quite as important at the boiler pressures we are discussing here. However, the use of the filters can be quite important and results have indicated removal of iron from 100 to 150

Fig. 9. Millipore Filter® tape

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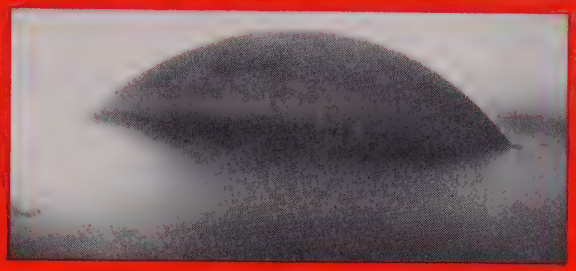

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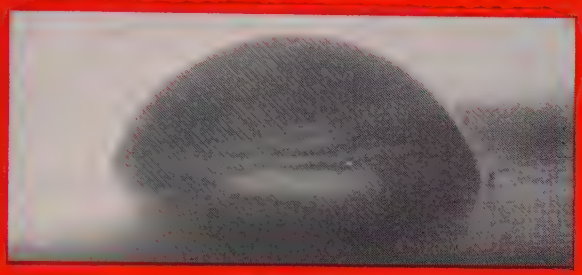

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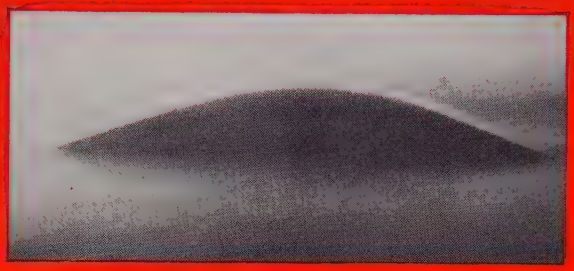

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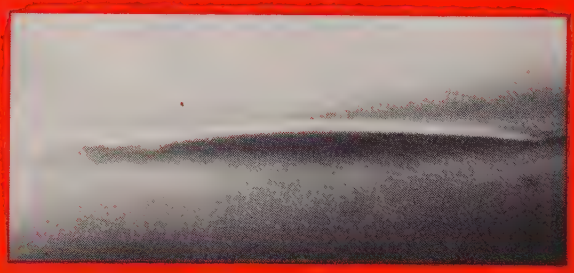

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These photomicrographs of water droplets (magnified 20 times) illustrate how Naugatex 2752 increases the contact angle of coated offset papers. The reduced surface wettability of the Naugatex-treated paper (left) compared with a competitive latex (right) is a direct function of the low surface activity exhibited by new 2752. Because of reduced moisture sensitivity, coated offset papers formulated with Naugatex 2752 present fewer printing difficulties due to scumming (wet-pick), plate tinting, and curl.

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p.p.b. down to the range of 5 to 10 p.p.b. Many types of filters have been used for this and we show on Figure 4 a comparison of filter designs.

Because of its ready accessibility and ease of cleaning, Graver uses the leaf type design extensively in condensate work. Figure 5 shows the Graver-Davis leaf filter which has been operating successfully for many years. Its self cleaning design with rotating sprays is particularly applicable to iron and crud removal. Solka-Floc is used for precoating. These filters can be designed for manual or automatic operation.

Most of the available experience on condensate scavenging has been on utility power cycles which are virtually closed cycles with low makeup. After the initial cleanout problems, which can be quite formidable, the contaminant level remains relatively low. Figure 6 indicates typical run curves with influent iron and copper as high as 25 to 30 p.p.b. This level of contamination allows a one-week filtration with a pressure drop of 18 to 20 p.s.i.g. and a filter rate up to 5 g.p.m. per sq. ft.

In an individual plant, contamination up to 100 p.p.b. is not exceptional. This means a shorter run length and lower filter rates. It also emphasizes the importance of self cleaning in the filters. Since it is difficult to predict iron levels, a pilot plant may be indicated. Figure 7 shows a small pilot plant which would enable actual work at the plant in order to set filter rates and indicate length of runs.

A new device which is proving quite helpful in monitoring iron and other impurities in the system is the Graver automatic tape analyzer. This was developed for condensate scavenging systems operating with high pressure boilers, and is being used at the present time in several large utilities. Figure 8 shows one of these units and Fig. 9 shows a typical Millipore Filter® (the testing medium). This unit continuously takes samples and shows the level of impurities in the system. It has the advantage of being automatic and portable so that it can be be placed at any point in the condensate system to determine the crud level.

CONCLUSION

A careful study of the various makeup systems listed is essential during the design of the boiler house. Since the type of treatment is seldom obvious, a complete study must be made taking into account all factors listed. A similar study should be made of the condensate system since it may involve even greater flows than makeup. The use of condensate filters for high pressure plants should be carefully considered to insure more complete reliability and less maintenance on the plant.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct 24-28, 1960.

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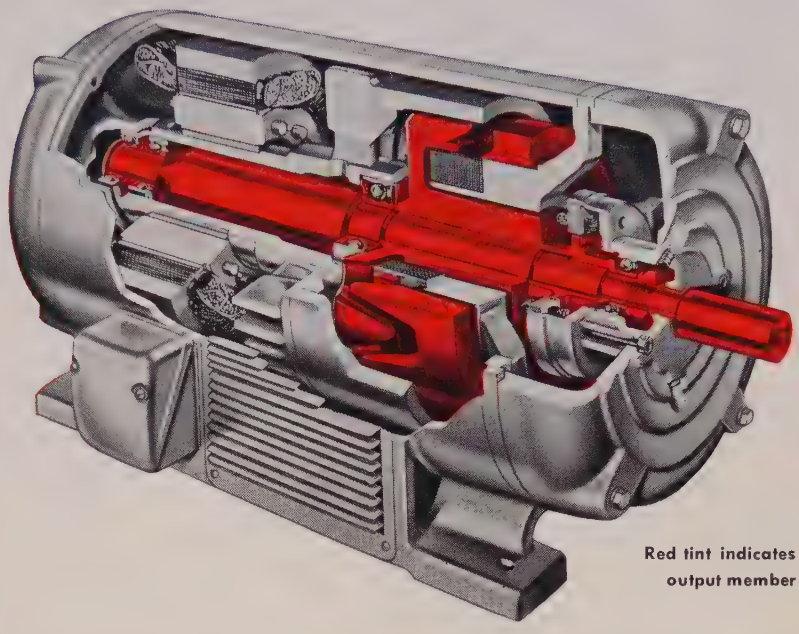

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RICHARD A. DANDO

The problems with boiler water treatment equipment and operation experienced at St. Regis Paper Co. plants are reviewed. These are typical of the problems which would be expected in the paper industry. The continuous operation which is required by this industry cannot be sustained by some types of treating equipment. Suitable allowance in design features must be made for maintenance and emergency operation. Internal boiler water and steam treatment should be considered as an integral part of the water treatment program. The internal treatment does not differ appreciably from other industries which operate with high make-ups, but special problems are caused by the corrosion in the steam and condensate system. Amine treatment for reducing corrosion is generally used. The iron corrosion that takes place during a paper machine outage presents a special problem. When this iron returns to the boiler, scaling, corrosion and priming may result, so that filtration of the condensate may be economically feasible.

You have just heard a discussion of the various methods of treating water for boiler makeup. I would like to carry this discussion further covering some of the problems associated with equipment design and operation from the viewpoint of the paper industry. In my position as a technical service engineer, I have had the opportunity to cover most of the water problems encountered at the major manufacturing facilities of the St. Regis Paper Co., and in the last five years, I believe that nearly all the problems that could be encountered have been covered at one location or another. Solutions of some of the problems have been found, but a continual program is being carried out on others.

The proper place to have eliminated the majority of the problems would have been during the design of the original system. This is possible only when the consultant, supplier, engineering, and technical personnel are thoroughly familiar with the requirements, and have all the information they need. Unfortunately, this is not always the case, and wrong assumptions are made due to necessity, and corrections must be made later.

Complete water analyses obtained frequently over a period of at least a year should be available on surface water supplies. This requires a considerable lead time before the equipment selection can be made, so it is usually necessary to use what data are available, and take steps to obtain the rest of the information and to keep the equipment supplier informed, so that modifications can be made if necessary. This can be very important on demineralizers which must be designed on the maximum solids in the water or on the chemical feeder size selected for a hot process softener if the water has a higher alkalinity than was previously reported. These are a couple of examples where the necessary follow-ups were not made in our company.

The operating requirements for the paper industry include a guaranteed continuous operation for years at a time with all repair and maintenance being accomplished "on the fly" or during a short mill shutdown. Some types of equipment cannot be expected to operate under these conditions, and alternate capacity or other means of permitting the outage time to be obtained must be supplied. For a short time and under controlled conditions (such as reduced steam output) boilers can be operated under adverse makeup water conditions. This may involve higher alkalinity, silica, and blowdown than desired, but the boiler water treatment plant cannot normally be used as an excuse for restricting mill production. This certainly should be considered in the original design, and suitable bypass piping installed. Clarification-type equipment, such as hot process softeners, are very sensitive to changes of flow rate and have a definite peak load which cannot be exceeded. The primary hot process softener is designed on the output basis and thus it is very easy to have a unit which is too small if you forget that this includes about 15% of your own steam that was used to heat the incoming water. I mention this because it has happened even though the original request was for a system based on the incoming water. Zeolite softeners and demineralizers will take surge loads easier, if conservatively designed, but the frequency of regeneration may enter the picture if sustained peaks are required and storage is inadequate. The water quality may not be as good as high ratings, but in this pressure range, can be tolerated for a short time.

In the equipment design certain water storage requirements must be considered. This appears to fall in three categories; (1) a storage required for operating the treatment plant, (2) a make-up water storage to meet surge make-up loads, and (3) a strictly emergency storage to take care of power failures, short equipment outages, etc. It is very difficult to tie these all together in one common tank as the operators then consider this as their emergency storage and will do everything in their power to maintain maximum water level in the tank, even to the extent of operating the treatment plant in excess of its maximum capability. Usually the operating storage can be built into the equipment as excess capacity or as an integral compartment. For most backwash and regeneration requirements some economy in operation can be obtained by separate storage, since fully treated water is seldom required for these applications. For the makeup storage the usual requirements need only cover the loss of a major condensate return long enough to make emergency repairs, or to eliminate contaminants that may be present following a machine startup. The storage following clarification-type equipment must be large enough to allow for bringing a clarifier or hot process softener up in load slowly enough to avoid sludge bed upsets. Not being an operator, I would think that the only emergency storage necessary would be that water necessary to allow for shutting down the boilers, or instituting emergency procedures (such as the use of untreated water), but this doesn't seem to be the case.

Other equipment considerations should include the expansion possibilities of the installation, and at times the disposal of the sludge or regeneration chemicals could be problems that must not be overlooked. Equipment suppliers seldom concern themselves with these problems.

The cost considerations are never overlooked in the installation of water treatment equipment and usually the lowest priced installation that will supply an acceptable water is installed. This should not be the case, and the overall cost picture should be included. This will cover not only the equipment installation and chemical feed costs, but also the internal boiler treatment cost with the blowdown heat losses, and something usually overlooked, but of major significance—the steam treatment cost. Nearly all our mills consider the treatment of steam and condensate for corrosion control a necessity. For many high make-up systems without hot process softeners or demineralizers, the cost of such treatment can be prohibitive, and it is definitely a significant part of the overall treatment cost with hot process treated water at high makeup levels. Therefore, the lowest cost installation may not be practical in terms of the overall picture.

Even with the best of pretreatment equipment some internal conditioning problems will be encountered. Usually a water conditioning chemical service engineer can set up proper conditions for internal treatment, and the boilers will operate reasonably well. The system of balances and checks that are required vary from situation to situation and in many instances the regular treatment which worked in a neighboring mill may not prove to be satisfactory. Basically, the internal boiler water conditioning should not vary from

RICHARD A. DANDO, St. Regis Paper Co., Carthage, N. Y.

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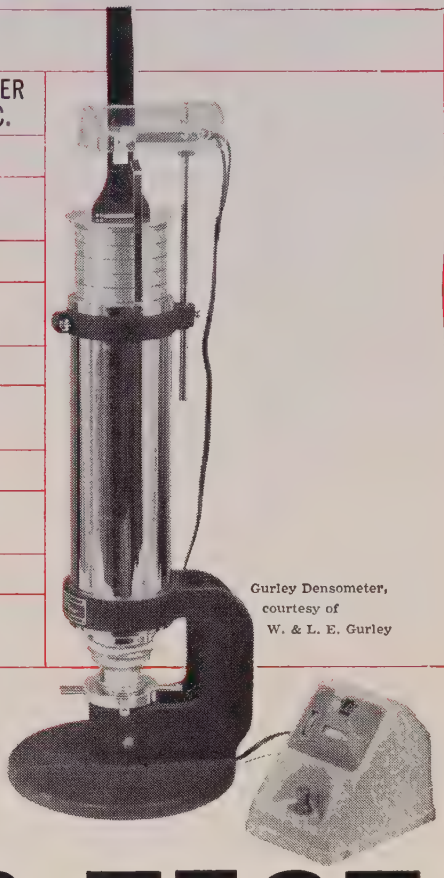

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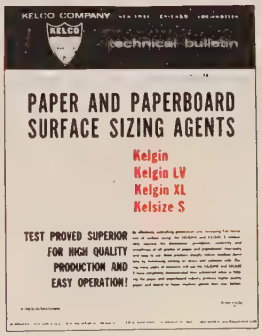

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one water supply to another in the chemicals fed, only in the amount of feed and the control tests required. Sometimes this is very difficult to explain to operating personnel. The normal chemical feeds are well known, sulfite to the deaerating heater storage or exit and the phosphate to the boiler drum with caustic if alkalinity adjustment is required. The reasons are covered in the texts and are basic, but the number of plants where these basic rules are not followed is amazing. Since a complete disucssion of chemical feeds and testing would take several hours, I will not go into this here, except to mention that sludge and scale samples for testing should be taken whenever a boiler is inspected internally. The analysis of these samples supplies clues as to poor treatment and troubles that should be anticipated. At lower operating loads these deposits may not be a source of trouble. The amount of iron, copper, silica, magnesium phosphate, or calcium carbonate in these sludges can be very significant. Generally, the internal treatment is good and tube failures resulting from scales and sludge deposits are rare, which is as it should be. Silica scales and turbine deposits have received so much publicity that the common practice today is to keep the silica residual in the boiler as low as possible. In some cases this appears to have been the cause of another problem, as bad or worse than the one it is curing, for unless a low phosphate residual is also maintained along with the low silica, magnesium phosphate tends to form whenever any magnesium hardness contamination is present. This is a sticky deposit which will not stay in suspension and be removed in the blowdown, thus causing a dirty boiler internally.

The internal inspection of boilers must include a thorough inspection of the steam purifying equipment. Inspecting behind some steam baffles which must be sealed thoroughly is sometimes a problem, since extra time is required to remove and replace them, but at the minimum an inspection plate should be installed so that at least some of the internals can be seen. I had the opportunity to see some steam drying screens that were partially plugged up with sludge. This had been the direct cause of superheater tube failures, and simple cleaning of these screens prevented the further loss of tubes. An inspection plate has been installed and the amount of extra time required during the outage to look at the screens is now minor.

The carry-over of solids in the steam may seem to have little to do with water treatment, but the operators will invariably question the water treatment when evidence of deposit in the steam lines are found, so that it falls on the water chemist to determine when the carry-over occurs and the probable causes. This excessive carry-over occurs much more frequently in this industry than would be expected.

The occurrence of extreme carry-over is shown by the drop in superheater temperature; but, to detect carry-over before it becomes so severe, conductivity measurement of a condensed steam sample should be employed. Since it occurs in slugs normally, it is very difficult to spot by grab samples; therefore, continuous recording equipment is required. Degassing equipment is not needed since the type of carry-over that occurs is readily picked up on the total condensed steam sample. The sampling requires a standard sampling nozzle in the header or steam line. The use of drain lines, while convenient, gives erroneous results.

The conditions causing carry-over are usually the swinging loads which cause high water levels in the steam drum, but other possible causes that could easily exist are a high alkalinity due to black liquor contamination, or oil contamination. A condition which we experienced in one case was a plugging of the steam screens with sludge from the boiler water. A priming condition must have existed for this to occur, and one of the suspected causes was a high turbidity in the boiler water due to suspended iron. Since this is a problem in most pulp and paper mills, I would like to describe our experiences which we hope will lead to a solution to this problem.

The source of magnetic iron oxide in the boiler water is largely from the condensate returns. Regardless of the type of iron in the condensate return, most of it is converted to the magnetic form in the boiler. With most types of treated makeup the iron has been reduced to a negligible amount, and with normal internal treatment, very little corrosion exists in the boiler, but corrosion in the steam and condensate system is a normal occurrence, and with the lower blowdown requirements of modern water pretreatment, especially with demineralized makeup, the iron becomes a serious problem. It can easily cause a high turbidity in the boiler water which could lead to priming and carry-over, high iron content scales or sludges which do not disperse readily and cannot be removed in the blowdown, or which cause active corrosion in the boiler. The iron in the condensate returns appears from two sources: (1) the normal corrosion due to carbon dioxide, oxygen or both in the returns and (2) the heavy slugs that occur following a paper machine shutdown. The first can be minimized in most cases by steam treatment with a volatile or filming amine. Controversial results have been obtained with filming amines, and in our experience their use in kraft mills has caused serious boiler scaling. In nonintegrated paper mills where there is no chance for black liquor contamination their use appears to be practical. Filming amines have not given a reduction in corrosion at points where steam velocities have been high, while the volatile amines have been effective. The volatile amines have given good corrosion control in our mills in nearly every instance, although the cost is high when the carbon dioxide level in the steam is high and excessive use of certain volatile amines can apparently cause corrosion of copper base alloys. The control of the volatile amine feed may be difficult if the quantity of makeup varies so that I would think that an amine feed pump paced proportional to the makeup flow would be desireable, for instance, when hot process softened makeup is being used.

The second source of iron in the boiler—that which occurs during a machine shutdown—does not lend itself to chemical treatment. The usual recourse is to dump the condensate until it clears up, but even with an apparently clear return, the suspended iron can be quite high. This loss of condensate which must be replaced with makeup will usually overload the makeup system, and removal of the iron so that the condensate can be recovered may be economical.

We considered and investigated various means of removing the iron. Since some of it was in the magnetic form, magnetic traps were part of the investigation. Simple tests using a magnet indicated that less than half of the suspended iron would be removed. Terry cloth filters were being used in some mills but the iron was in such a finely divided state that we could not obtain the desired removal on a laboratory basis. This left us with only a precoat filter as a possible solution unless we went to full chemical treatment involving coagulation, settling and filtration. Laboratory experiments showed that filtration through a precoated filter would remove practically all the suspended iron, and we felt that we could reduce the soluble iron to an acceptable level with partial or full amine treatment. A precoat filter has been installed in one mill and, after evaluation, several more installations will undoubtedly be considered. The suspended iron removal has been very good. In discussion with other members of the industry, we found that this problem was not limited to our mills.

Water treatment for boilers with a high makeup presents many problems, but most of these can be overcome by proper selection of equipment. Though chemical additives are known to help in some situations, the less reliance put on this solution, the better the overall operation, probably because the operators can understand a mechanical operation, while a chemical treatment is forever a mystery.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

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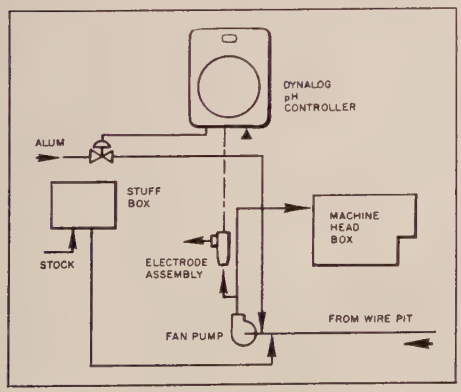

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Analytical Instrumentation

Why the Power Department Should Supervise the Operation of Recovery Boilers

H. R. ARNOLD

Chemical recovery boilers, by design and operation, are no longer operated primarily to recover chemicals. They serve a two fold purpose, to recover chemicals and to generate steam, and, because they involve high steam pressures and combustion furnaces, should logically be placed in the same category as power boilers. They should always be placed under the jurisdiction of the engineer in charge of the power plant. The power department, rather than the pulp department, is best staffed with operators qualified to operate and maintain these boilers.

From the beginning, chemical recovery units in the paper industry have been operated under the supervision of the pulp mill foreman. This is understandable when we remember the old rotary units which were used to burn and reclaim the chemicals.

Because we are a progressive group, intent upon manufacturing our product less expensively, our engineers quickly realized the need to reclaim the wasted heat from this process and utilize it in the generation of steam which is so important to the manufacture of paper. By superposing a boiler in the path of the exit gases from the smelter, fair results were obtained. The additional steam generated in this manner permitted the use of more electric power when used in the turbogenerators and served to make use of more labor saving devices and in turn to reduce the cost of the end product. More than 30 years ago, we realized the importance of this by-product, steam, not only to use in our process, but to generate the electric power. Subsequently, the increase took place more rapidly than we expected or could visualize. This condition was brought about partially by the need for better production controls, a higher quality product, and the addition of considerable service equipment. Whereas in the earlier days, we felt comfortable if we had the capacity to provide 500 kw.-hr. per ton of pulp and paper; present day mills are using up to 1100 kw.-hr. per ton when bleaching is incorporated.

With the introduction of boilers in the chemical recovery system, most mills still followed the old custom of operating them for the primary purpose of making smelt. The steam generated was piped to the power plant for their use, and for the most part we must agree that it was an unsatisfactory source of steam, because blackouts and plugging of the boiler passes very often resulted with loss of stream pressure and variations in frequency that affected the overall mill operation. During this period the Power Department was called upon to assume a portion of the responsibility for the operation of the recovery boiler, generally water tending, water treatment, and maintenance of the pressure parts of the units. This system of operation has been in use for many years with the Power Department becoming more and more involved and affected. Power engineers, cognizant of the need for firm steam from the recovery boilers, have been called on to assist in the selection of the units, sizing of fans, instrumentation, types of auxiliary drives, and all factors affecting the mill operation in order to maintain an economical steam and power balance. Their initiation into this phase of the operation has resulted in further increases in steam pressures and temperatures, until today, we have no hesitancy in operating recovery boilers at 1250 p.s.i. and with steam temperatures up to 900° FTT. At these elevated pressures and temperatures, the power supervisors have been brought closer to the operation, and necessarily so because of their training and background in the operation of boilers. Closer control of furnace conditions, auxiliary fuels, feedwater conditioning, boiler inspection, and maintenance of the auxiliary drives and boiler appurtenances is a function that in many mills has been passed on to the power plant supervision.

In spite of the trend in passing on more and more of the responsibility for the overall operation and maintenance of the recovery unit to the power supervisors, we continue to maintain a split responsibility between the power supervisors and the pulp mill supervisors. Regardless of how well they might cooperate, split responsibilities will ultimately affect the overall operation and availability of the boiler, either by poor combustion of the fuel or poor chemical reduction.

The recovery boiler as we use it today is neither primarily a chemical reduction unit nor a steam generating unit. Its primary function is twofold, for it must be operated both as a steam generator and for good chemical reduction, producing high quality smelt and firm steam that can be efficiently utilized in the generation of electric power, and extracted for process requirements. Unless we obtain this condition, we must have reserve equipment or capacity to meet the demands, which in turn means a greater capital expenditure. Who then should be charged with the responsibility for the operation of the recovery boiler? The burning of black liquor is not entirely for the purpose of making smelt; it, therefore, becomes a fuel, not too different from the fuels consumed in other furnaces where we insist that we have trained men who realize the complexities and the dangers involved in burning fuels, and who are trained in the operation of boilers. As in many other fields, power supervisors are becoming more specialized and are better able to assume the added responsibilities of operating recovery boilers with their advanced engineering designs. Why, then, do we not take advantage of their training and break through the barrier of antiquated customs? They have the "know how," as one mill experienced about five years ago, when the supervision of the recovery operation was placed with the Power Department. Within 3 months, they were able to reduce their purchased fuel costs substantially, and with a corresponding increase in chemical reduction.

Presently in the south, there are many mills who have adopted this method. The new bleached food board mill for the Continental Can Co., planned the steam and power facilities to incorporate the black liquor evaporators and the recovery boiler into one power and recovery area.

What is the attitude of management and the insurance companies toward such a move? In general, I have found that in most cases, management dislikes split responsibilities, but tolerate this condition because of the established precedent, while in some of the larger mills, it has not been given favorable consideration due to the physical location of the recovery boilers. Neither of these reasons is valid when it is realized that other progressive companies in the industry have taken this forward step, and for a good reason.

Recovery boiler manufacturers and insurance underwriters have for many years expressed a preference to have recovery boilers operated by the Power Department. As far back as 1952, one of the major insurance underwriters issued an "Accident Prevention Bulletin" entitled "Guard Against Furnace Explosion in 'Chemical and Waste Heat Recovery Boilers.'" Under the subtitle of operation and maintenance, it reads, and I quote:

> "Recovery boilers, even though their primary purpose is chemical recovery, should be placed in the same category as power boilers. They should always be placed under the jurisdiction of the engineer in charge of the Power Plant. In our opinion, the Power Department, rather than the Pulp Department, is best staffed to operate and maintain these boilers."

It is not the intention of this paper to cast any reflection on that fine group of men in the Pulp Department, who for years have been burdened with this responsibility and con-

H. R. Arnold, Supervisor of Steam and Power Engineering, Continental Can Co., Inc., Greenville, S. C.

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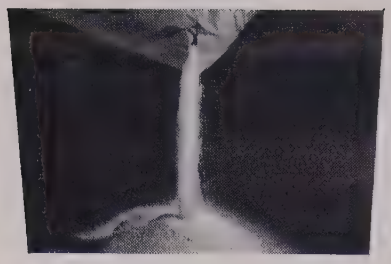

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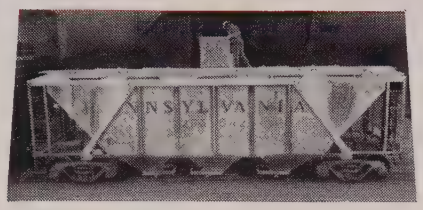

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tended with a problem which over the years has become increasingly significant. Why do we hesitate to place the responsibility of its operation where it belongs, namely on the power plant personnel, and permit the pulp mill personnel to manufacture the quality pulp required for the manufacture of paper in this highly competitive market? That, in itself, is a full time job and worthy of every minute of their time. The power plant supervisor is qualified and willing to assume this addes responsibility and you may rest assured that he will give it the care and attention required to produce the best results obtainable.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

Training of Power Plant Personnel

MILTON F. GINTER

The Power Department at the Dow plant in Midland, Mich. employs about 370 for which a training plan was developed, covering the various job classifications. The overall instruction given is outlined.

To BETTER understand the scope of the job we have to do in the Power Department at the Dow plant in Midland, Mich., we will attempt to give you a bird's eye view of the functions and size of its operations.

We have three major power plants within the confines of the plant. The plant covers about 2 sq. miles. These three plants are all interconnected, both steamwise and electrically.

We have 16 boilers, the largest of which is a 650,000 lb. per hr. unit. We have 16 turbo-generators, the largest of which is a 40,000 kw. unit. We operate and maintain this equipment. Central shops are used only when we have an overload of work.

Our total generating capacity is 200,000 kw. per hr. and 4,500,000 lb. of steam per hour. Eighty six per cent of the steam is generated at 1250 lb. pressure and the remainder at 400 lb. pressure.

The department has personnel numbering 370 people. About 215 of these people are engaged in operations, 100 in maintenance, and 35 in instrument and control. The remainder are staff and administrative.

Our department is a single seniority department, that is, all employees covering operations, maintenance, and instrument and control are on a single seniority list.

With the changes that came about in the late 1930's and early 1940's, we came to the realization that education, if it were to give the necessary results, could no longer be on a strictly voluntary basis.

Our first step was to go to a progression schedule. This lined up each classification such as fireman, engineers, etc., permitting cross-bidding at lowest classifications only. This gave us some control but certainly did not give us qualified, trained people.

In 1944, we negotiated a training program in agreement with the Union. The agreement stipulated training as a prerequisite for each step in the progression schedule.

A committee composed of the top supervision in the Power Department was formed and working in conjunction with the Educational Department, setup "on-the-job" training courses for the different classifications.

We started out with three trial courses. These proved very successful so we extended the program to cover all of our functions. A full-time instructor was obtained from the Eductional Department and assigned directly to the Power Department. Utilizing this setup to its fullest extent, we tailor-made our textbooks to fit our particular equipment.

Along with our courses, we had each plant engineer write full operating instructions for all major equipment and when a man took over a job involving this equipment, he signed his name in the book indicating that he had read and understood all of the instructions.

We set up a classroom and fully equipped it with all of the visual aids that we felt would be of assistance in putting over the program.

One of the biggest visual aids we discovered was to mark the actual equipment, take pictures of it, and use it in our classroom work.

At the height of the program, we were training as many as 225 men, giving them one 2-hr. class per week. It required about equal time in off-the-job study.

About 1400 diplomas have been awarded to the Power Department employees.

At the present time, we have over 100% of trained replacements so we have discontinued most of our regular courses.

The maintenance course, to a large degree, is made up by using standard material which is available from the manufacturer. Visual aids are incorporated such as displays of tools and their uses. Sales engineers are utilized to give talks on the proper use of their equipment. Some of the tools such as micrometers, verniers, and protractors were enlarged 10 times and used for classroom demonstration.

We have offered a course in advanced maintenance to a limited number which will develop a trade technician, making the employee capable of qualifying as a journeyman in several trades.

The instrument and control training is probably the most formal. It is equivalent to or better than the 2-yr. courses which are offered to develop technicians in the electronic and electrical fields. This course requires 600 hr. of classroom work and an equivalent amount of off-the-job study time plus the requirement of demonstrating actual ability to put the training into effect on the job.

This course is being handled by the main Educational Department and we have an enrollment of 30 in the class.

When we install new equipment different from that which the men have been trained to handle, we run a short course with the aid of the manufacturer, instructing the men who will operate this equipment in the proper procedures. We also include in this group an equal number of men, who, according to the progression schedule, will be next in line for the job as well as all supervisors who will be in any way involved with the equipment.

In the selection of employees coming into the department, we are probably in the same position as most other companies that work with organized labor. You are governed, particularly in transfers, by the existing contract. On new employees, however, we do have a battery of tests given by the Psychology Department indicating the man's aptitudes and abilities. We are fortunate that one of the requirements for entrance into the Power Department has been a high school education and we have held steadfastly to this requirement.

Our line supervisors are taken from the ranks and we feel that this has been a very satisfactory procedure. When a man is selected as a candidate, we have available a complete battery of tests and consultation services from our Psychology Department. We use this not as a method to screen out but rather as an indicator of the man's ability to successfully fill the job.

We are tending to start at the plant engineer's level to fill these vacancies with technically trained personnel. In other words, plant engineers, assistant superintendents, superintendents, and results engineers will be men with B.S. degrees in either electrical or mechanical engineering.

Our practice is to interview these men after they have been recommended by the Technical Employment Depart-

MILTON F. GINTER, Assistant Manager, Power Dept., Midland Div., The Dow Chemical Co., Midland, Mich.

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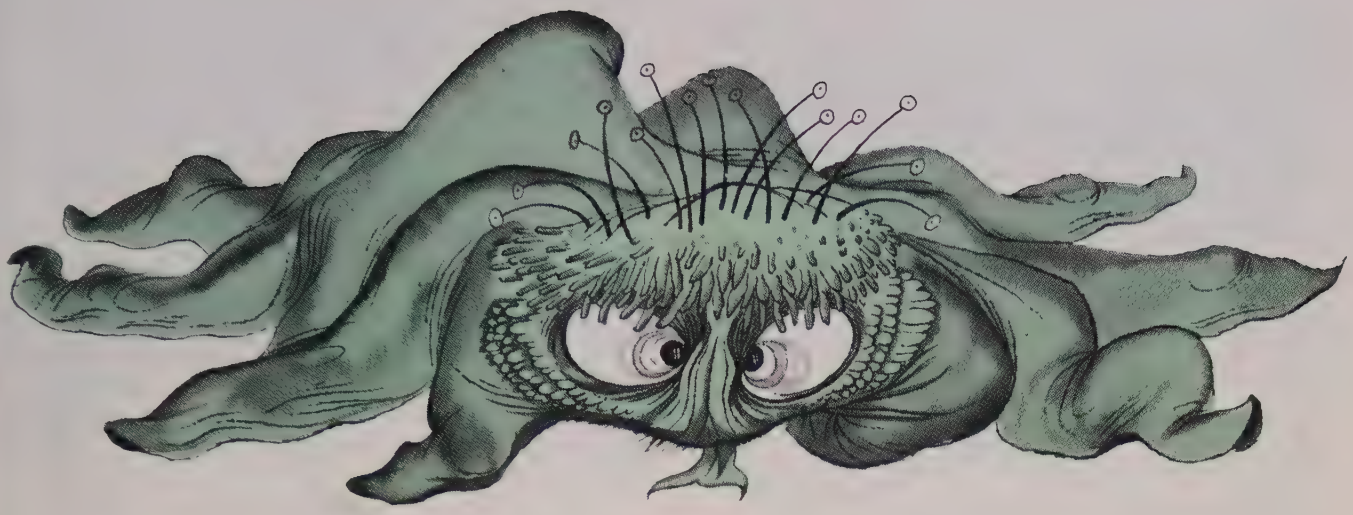

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ment for the power field. We normally try to procure those people in the upper 20% of their class. In interviewing, we look for a definite interest in the power field; a type of mind that is open for progress, and possessing an ability to live with other people.

Our straight staff jobs are few.

We put these new technical men on definite job assignment as a very short introductory period. The work they do will have a definite end result. We do not move them from one group to another just for the sake of so-called "experience."

With our supervisors, the training is more plant wide, such as extension courses from the university on human relations, etc., and we rotate the people we send according to their interest level for that particular meeting. We have given rather extensive training to our supervisors in industrial psychology. We make sure that he understands all phases of the labor contract.

Classes are initiated regularly where the functions of all the departments, even including Accounting and Salary Administration are explained. These meetings are put on right after work with question and answer periods following the dinner.

We have a 1-week course on general foremanship training which we give to all our supervisors. This is handled by the Plant Educational Department.

We have come to the conclusion that:

1. Those things which people actually work with are easier to sell for training programs.
2. Training for operation should be directed to the equipment involved with not too many "frills."
3. Maintenance and instrument and control are the hardest courses to sell and much harder to assemble.
4. Formal training, that is our regular courses, can be completed and terminated and do not have to be a continuing expense.
5. Refresher courses and information on new equipment are a "must."
6. Training (provided you don't try to create a "monster") has a very definite place in the power field and will pay a very generous return for every dollar expended.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

Training of Plant Personnel for Large Central Stations

W. S. TIERNEY

Training of power plant personnel is discussed generally, indicating the necessity for an organized program.

THE training of plant personnel for power plants presents a challenge to management regardless of size of plants, their age, or complexity. The author is connected with a large investor-owned electric utility which has been operating central station type of generating plants burning solid fuels since the turn of the century.

We have at present, six large thermal plants with an installed capability of nearly 3,800,000 kw. of capacity—the oldest of which was placed in service in 1914, and the latest in 1956.

During this period, all aspects of the plants have undergone change. Steam conditions have risen, size of boilers and turbines have greatly increased in capability, and instrumentation has been developed to the point where automatic operation of large generating units is an accomplished fact.

W. S. TIERNEY, Operations Engineer of Power Plants, The Detroit Edison Co., 2000 Second Ave., Detroit 26, Mich.

Fig. 1

This rapid advance in the art has made it imperative that well trained operating personnel is available to supervise and operate such complex plants.

There are a number of reasons for training, but to mention a few, the following may be considered: (1) to provide safe working conditions for the personnel, (2) to properly evaluate operating conditions effecting safety of equipment, (3) to obtain efficient operation, (4) to eliminate costly operating errors, (5) to provide a good Union relation climate, (6) to insure thoroughly trained people for supervision and management of power plants.

Training of plant personnel has evolved from what might be called training by association to a more formalized program. The first method was a hit-or-miss affair which was not only common to the electric utility industry, but to most industries. The ambitious people got on-the-job training from older operators, they provided the top class of people in the plants. Likewise, in our organization, trained steam operators were available from the lake and ocean steamship operating companies. During the 1930's, the pressure temperature conditions and size of units increased very rapidly. This condition, when carried over into the war years with the subsequent drain of top operator material to the armed services, made it imperative that a more formalized training program be developed to eliminate costly operating errors and unscheduled outages of important equipment to the system. More recently the refinement and adoption of automatic control monitoring systems added to the complexity of operation, again dictating the need for better operating personnel.

Our most recent power plant addition, the River Rouge

Fig. 2

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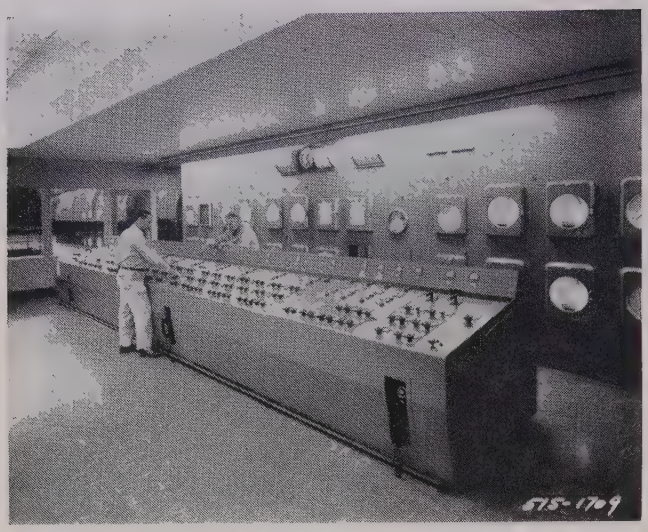

Fig. 2A. Boiler control panel

power plant shown in Fig. 1, has benefited from the evolution of training in our company. The description of the operator's training program for this plant, placed in service early in 1956, may be of interest. This plant contains three large reheat units, having one boiler supplying steam to one turbine. They are individual units not interconnected and are controlled from separate control rooms with a common central electrical control center.

Figure 2 shows the control room giving an idea of the complexity of this centralized equipment.

Figure 3 shows the organization of this plant. The superintendent responsible for the operation of this plant was selected in 1953 and given the responsibility for the selection of his staff, and the operating and maintenance personnel to place it in service and operation. They first selected principal staff people, they in turn selected the operating and maintenance personnel. These steps were taken prior to operation in 1956.

Such a selection schedule permitted intensive training of the operating personnel without interference. They had come from the older plants where, due to plant design, they had operated in one portion of the plant. For instance, our older plants are divided into three operating sections; namely, boiler room, turbine-condenser room, and electrical. In the new plant, these operating divisions were eliminated.

When the shift supervisors and their assistants were selected, a thorough cross-training program in all phases of operation was initiated. This was carried on in other power plants in the company. This program was the basis of our operation at River Rouge. Similar training was given to all operators in varying degree. The second part of their training involved so-called technical education. By this time, the construction of the plant was so that there was equipment on

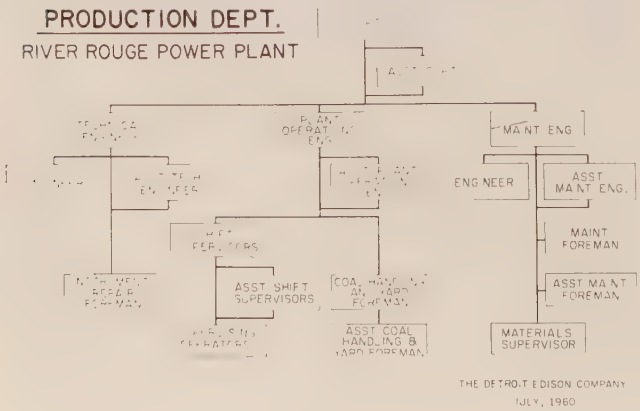

Fig. 3

the site in various stages of assembly. They were shown this equipment and discussed with them by the designers, the equipment suppliers, and their own supervisors. Models, diagrams, blueprints, movies, and similar ideas were used in this so-called technical phase.

A valuable instruction tool was a tape recorder. It was possible, by recording the description of equipment by its designers, to replay such a discussion many times after the original session.

As a part of this program, so-called instruction units were prepared which were used by the supervisors in later sessions to review this information. These are now a part of the instruction equipment available for the training of new operators.

The second phase in the training program was on-the-job training. This was scheduled to start prior to operation and, of course, has been a continuing program since the plant started to operate. Likewise, for the on-the-job program, instruction material was prepared by the supervisors as an

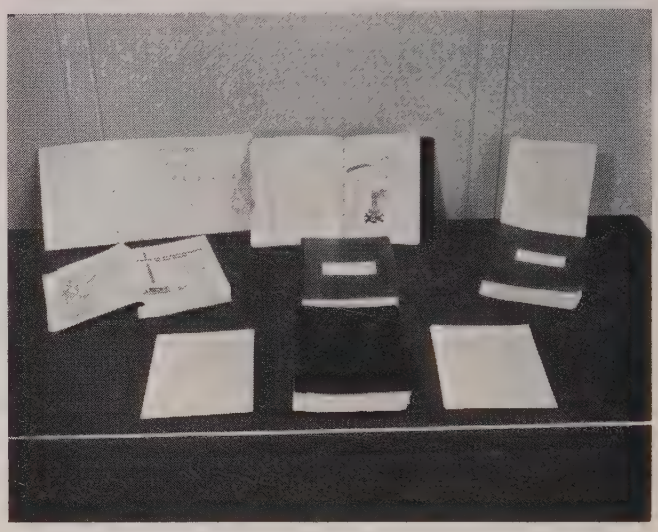

Fig. 4

aid in passing on training to their employes. Extensive use was made in this preparation of the JIT or job instructor training techniques developed and used during World War II.

Concurrent with training just described, electrical and mechanical theory classes were and are held for the operating personnel. The mechanical instruction is for the purpose of assisting in the obtaining of City of Detroit steam operating licenses. Such licenses are required in varying degree in all six plants of the company although only two are within the corporate limits of Detroit. The electrical theory work is required for certain of the higher operating jobs. Figure 4 gives an idea of the mass of material that has been prepared by the supervisors in the River Rouge power plant.

In summing up this discussion of training, there are several requirements that must be met. First and foremost is the desire of the superintendent and his supervisors to give their people training. Attempts that we have made where this was not the condition have failed miserably. Our successful programs have been built on the ability to have the first-line supervisor accept the responsibility of training for his people and being a part of the team that prepares the training material.

The rewards of a good training program are high—operating errors are minimized, plant efficiency is high, the safety record is excellent, there is good morale, and good operators and supervisors are the result.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

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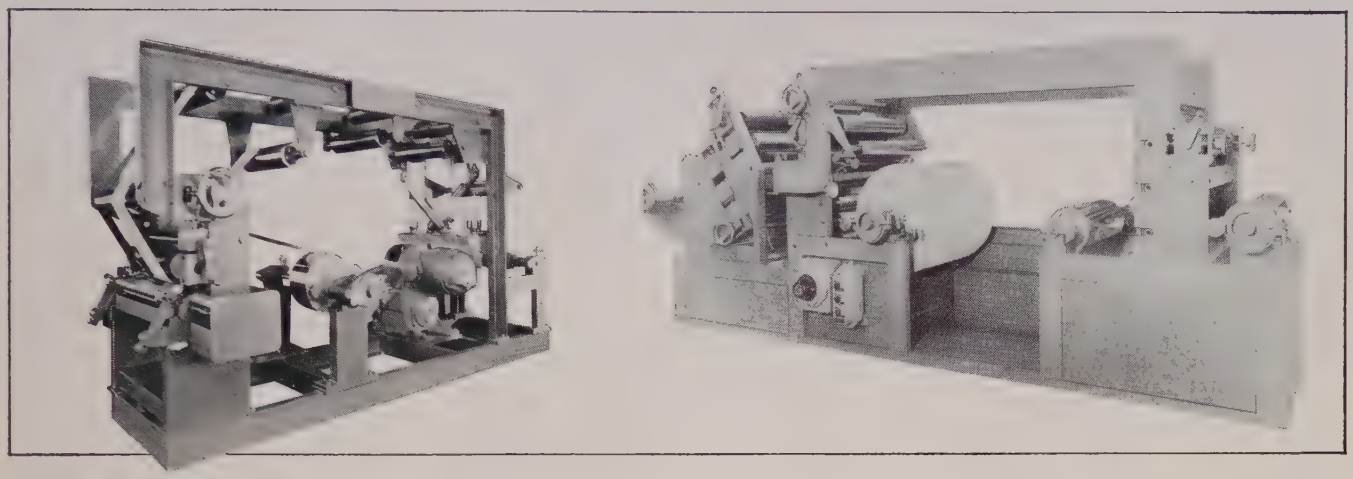

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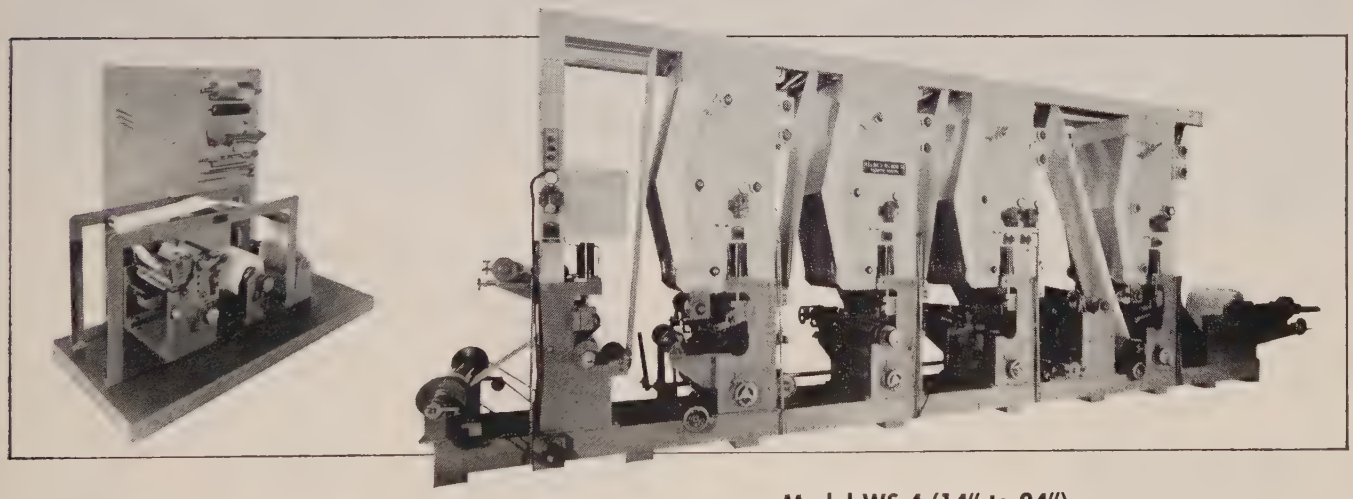

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Power Plant Operator Training

JAMES W. HERRINGTON

The program of training is an action program: a three fold one in which the trainee is told how to do the job—shown how to do the job—and actually does the job. Training programs in use for all operating jobs in the Steam, Power, and Recovery Departments follow the same general outline and procedure. It has been found that the strongest part of the program is that it is detailed and tailored to the job for which the man is being trained. When a job vacancy occurs in the department, it is filled by internal movement of men. The lowest classified job then becomes open and is filled through selection of men bidding for the job from the plant or forestry department. Formal training is minimized as a matter of economics.

It is indeed a pleasure to be here today to outline the "Power Plant Operator Training Program" as conducted by The Buckeye Cellulose Corp. of Foley, Fla.

First of all I would like to give you a brief background look at Buckeye so you will see why we are interested in people and the training of people.

Training has played a vital role in our successful development of a skilled, coordinated work force at Foley. It was decided when we located at Foley that we had a considerable responsibility to a small community. Inasmuch as we were replacing one of the major sawmills in the area which accounted for a large percentage of employment, it was felt that insofar as possible we should employ local people to staff our mill. Since there were no paper mills in the area, it meant that the vast majority of our people had never seen a paper mill before. As a matter of fact, 80% of all people employed at our Foley mill are from the immediate area. The other 20% came from Procter and Gamble installations and most of these had never seen a paper mill either.

I am sure that you will agree that we faced at the startup a tremendous training program to be sure that each of our supervisors, as well as key operators, knew his job. We started on this training approximately a year before startup.

At that time the mill was never enough to completion, although actual startup was a year away, so that it was possible to begin to see what the layout would be. Furthermore, the engineers and process development people had thoroughly in mind the operation of the equipment as it would be when completed. We spent about 2 weeks with each of the process engineers in an area, in discussing the operation of their department. The supervisor who would be in charge of that area then started writing a training program for his foremen. This was done in considerable detail to allow checking of the actual installation, so that mistakes could be caught before actual startup.

About 6 months after the supervisors reported, the foremen began to arrive and the supervisors then had the process well enough in hand so that they could train the foremen.

We have found that an excellent way to train people is to have them train others, so that the supervisors' training was partly accomplished by training the foremen. The foremen then wrote up training programs for their key operators in exactly the same way the supervisors had for the foremen, and this process was just as effective.

About 3 months before startup, the key operators started to arrive and were trained over a period of about 6 weeks. At that time it was possible to have prestartup inspections of the various areas, running then not on pulp but on water, or just dummy operations, to be sure that equipment would operate as engineered. Through this thorough training we were able to startup and operate the mill with a minimum of trouble.

James W. Herrington, The Buckeye Cellulose Corp., Foley, Fla.

POWER PLANT OPERATOR TRAINING

Our program of training is an action program: a three fold one in which the trainee is told how to do the job—shown how to do the job—and actually does the job. As power plant superintendent, I have overall direction of the program.

Training programs in use for all operating jobs in the Steam, Power, and Recovery Departments follow the same general outline and procedure. We have found that the strongest part of the program is that it is detailed and tailored to the job for which the man is being trained.

How Jobs Are Filled

When a job vacancy occurs in the department, it is filled by internal movement of men. The lowest classified job then comes open and is filled through selection of men bidding for the job from the plant or forestry department.

The orientation portion of our program, which I will discuss later, is omitted from the training program of a man already in the department and merely moving to a new job. However, the man coming in to fill the lower job usually is not familiar with any phase of power plant operation. As a matter of fact the last three men to successfully apply for openings were from our forestry department. The entire plant was new to them and the training program included a section on orientation.

Formal training is minimized as a matter of economics. Our approach, which has worked favorably for us, can be explained as one similar to learning to drive an automobile. It is necessary to learn the proper steps in the proper sequence. The "rules of the road," the "feel" of the car and its limitations must be learned. It is helpful to properly interpret the instrument board of the car and have an "ear" for sounds it makes when running properly. It is not necessary to know whether it is two cycle or four cycle, six cylinder or eight cylinder, or how to make repairs, etc., in order to be a good driver.

This sequence is followed in our training program. Equipment the men will be dealing with, the operating steps to startup and shutdown, the check points during operation, and the proper interpretation of danger signals as told the trainee by various instruments and the sound of the running equipment—is of paramount importance. It is not necessary that he have a detailed technical background and knowledge of his equipment in order to be a good operator. Our training programs point to this basic learning with a minimum of technical training.

DETAILS OF A TRAINING PROGRAM

Our "steam and power auxiliary operator" is the lowest classified job in our department. Since it covers the entire program and deals with a new man coming into the department, I will cover it in detail.

The first step is a preliminary and get acquainted talk in the office. Then the trainee is given a loose leaf binder which contains his entire training program. This training manual is divided into sections as follows:

1. Job description
2. Outline and time schedule
3. Training questions
4. Notes and sketches
5. Safety rules

As power plant superintendent, I go through the training manual and discuss it in detail with the trainee. In this discussion the trainee learns the exact procedure he is to follow in his training program. Two weeks "on the job" training time is needed for this particular job.

Administration of Program

In general, after the so-called "orientation" portion of the program, the trainee works with an operator on the job. The

"... beyond a doubt the finest press we ever had"

. . . says William J. Hurrell, Plant Production Manager,
Etobicoke Plant, Hinde & Dauch Paper Company of Canada, Limited

"The new HOOPER-SWIFT 900 Series Printer Slotter performs exceptionally . . . particularly on the heavy, intricate, complex display-type printing that is much in demand today." Mr. Hurrell ought to know. He's had years of experience with a company that operates seven corrugated plants, one fiber plant, two mills and a specialty division.

"Our press operators like it very much."

Referring to one of the many new and improved features of the 900 Series, Mr. Hurrell states, "The driven fountain provides the finest ink control our operators ever had." He continues, "Hooper-Swift presses are well constructed, standing up under rough usage. They continue to turn out a satisfactory product even though a number of operators have been on them over the years." Whether you're a large manufacturer such as H & D, or of more modest size, there's a new Hooper-Swift 900 Series to fit your needs. The basic unit is designed to "grow as you grow" with add-on features as business demands. Sizes: 35″ x 78½″, 50″ x 88½″, 50″ x 103½″, and 50″ x 113½″.

"Extremely suitable for producing high quality boxes at high speed."

The H & D Etobicoke plant has a gigantic capacity of 75 million square feet of corrugated board per month. Products vary from one extreme to another . . . from heavy duty boxes to fancy, multi-color display work. Says Mr. Hurrell, "Seven Hooper-Swift printer slotters (four are shown in photo) work exceptionally well for our particular situation . . . producing at high speed under an unlimited number of operating conditions."

FOR COMPLETE INFORMATION on the printer-slotter that "grows as you grow" or any other container making machinery, write: KOPPERS COMPANY, INC., Hooper-Swift Container Machinery Dept. 2703, Glenarm, Md.

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shift foreman spends at least an hour a day with the man. Two conferences each week of approximately an hour each are held in the office with the purpose of determining the progress of the man—and to clarify any confusing matters.

To show exactly the procedure followed, a page from each section will now be covered.

I. Job Description

I. Area of Work
   Primarily at ground level, entire power plant area, exclusive of evaporators and recovery boilers.

II. General Duties and Responsibilities
   General responsibilities are for starting, hourly operation checks, stopping and securing all auxiliary equipment in the steam and power area.
   General duties are to perform the physical acts, in accordance with instructions to place equipment in service, operation checks, to shutdown and secure, and maintain records.

III. Specific Duties and Responsibilities
   1. Start, operate stop factory air compressors.
   2. Periodic check on factory air compressors: lubrication, unloader, temperatures, pressure, cooling water, etc.
   3. Perform prestartup checks at ground level for power boilers.
   4. Perform steps necessary to start, operate, stop forced draft and induced draft fans.
   5. Make hourly checks on forced and induced draft fans and turbines: lubrication, cooling water, reduction gear, bearings, damper control drives, etc.
   6. Perform prestartup checks at ground level for power generating turbines.
   7. Manipulate steam drains.
   8. Start, operate, stop gland exhausters and vapor extractors.
   9. Make hourly checks on power generating turbines at ground level: cooling water to oil and air coolers, generator air coolers, etc.
   10. Start, operate, stop all ground level equipment for the 1500-kw. turbine: condenser cooling water, condensate pump, air ejectors, hot well recirculation, steam drains, etc.
   11. Etc.

Under "Specific Duties and Responsibilities" the trainee learns the equipment he will be operating and what he is supposed to do. One hazard that is prevalent when attempting to define a man's job is the possibility of omitting some responsibility and then having an unpleasant situation develop when this responsibility is added. Thus far we have been able to "head-off" this situation by explaining in the training program that the job description does not contain an exact listing of job requirements and that each operator may be required to do other job related duties than those listed.

II. Outline and Time Schedule

I. Orientation
   A. General tour of area
   B. Meet personnel
   C. Acquaintance with facilities: lockers, toilets
   D. Water fountains
   E. Safety, shift safety meetings, safety rules

II. Equipment and Equipment Operation
   A. Light fuel oil system
      1. Purpose of light fuel oil
      2. Storage tank
      3. Pump
      4. Relief valve
      5. Piping
      6. Start, operate, stop
      7. Receiving of trucks, ticket handling
      8. Inventory procedure
   B. Heavy fuel oil system
      1. Storage tank
      2. Suction heater
      3. Flame arrestor
      4. Strainers
      5. Turbine pump
      6. Motor pump
      7. Automatic starting of motor pump
      8 Pump relief valves
      9. Piping to boilers
      10. "In line" heaters
      11. Steam tracing
      12. Fuel oil unloading
         (a) Receiving of trucks, ticket handling
         (b) Strainers
         (c) Pumps
         (d) Hose and piping
      13. Etc.

This is only one page of eight used for the outline and time schedule. Each trainee's daily assignments are made by writing in the margin of the outline the dates on which each piece of equipment or operation should be studied. We feel that definite guidance as to daily activities of each trainee is necessary to permit complete coverage of the outlined program. This also keeps the trainee on a straight, chartered course and prevents him from jumping from one training project to another.

In order to further stimulate thinking on the part of the trainee, there is a section on training questions and a set of questions for each major division of the outline and time schedule. There are 13 pages of questions in this section of the training program with a total of more than 200 questions.

III. Training Questions—Light and Heavy Fuel Oil Systems
   1. What is meant by light fuel oil?
      (a) Why is it needed?
      (b) Where is the storage tank? What is the tank capacity?
      (c) What type pump? Why is a relief valve provided?
      (d) Trace piping to points of usage.
      (e) How often is tank inventory taken? Who does this? What is done with the information?
   2. What is meant by the heavy fuel oil system?
      (a) What is capacity of the storage tank?
      (b) About how many gallons do we use per day?
      (c) Why is a flame arrestor provided on top of the tank? How does it work? How often is it inspected and cleaned?
      (d) What is the suction heater? What means is provided to control oil temperature?
      (e) Trace piping to pumps.
      (f) How many strainers? What type? How often cleaned? Who cleans? What precautions are necessary?
      (g) Why is one pump driven by a steam turbine and the other by a motor?
      (h) Which pump is normally used?
      (i) Explain "automatic" starting of the motor pump.
      (j) Why are relief valves provided at the pumps? What are set pressures?
      (k) What checks and precautions must be made before starting the steam turbine pump?
      (l) Does the turbine pump run a constant speed? How is speed controlled? What do you do if the turbine accidentally trips out?
   3. Etc.

IV. Notes and Sketches

The section on notes and sketches contains 20 sheets of blank paper for the trainee to use as he sees fit in completing his training schedule.

V. Safety Rules

This section contains a copy of our department safety rules. These rules will not be reproduced here, but each trainee is required to thoroughly familiarize himself with them.

RECENT ADDITION TO PROGRAM

When we converted our power boilers to natural gas last year, we made an addition to our training program that is not shown in the basic training manual. As we feel the necessity to revise the individual training programs, this section will be added. This addition "ties together" the efforts of several operators to accomplish an operation as follows:

They go hand in hand with more printable papers

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Coast-to-coast warehousing, Shawinigan's large staff of research chemists who are ready to help you with your particular problems, and highly trained field representatives add up to an organization that can help you improve your products and your profits. Write to Shawinigan Resins Corporation, Dept. 8R, Springfield 1, Massachusetts.

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GELVA® *polyvinyl acetate resins by* **SHAWINIGAN RESINS®**

POWER BOILERS—GAS BURNERS FIRE UP ON GAS—BURN GAS

	What to do	Who does it	Why it is done
1.	See that the boiler is made ready for firing: access doors closed, drum vent and superheater drains open, water level correct for firing, etc.	S & P operator Turbine operator	So that no damage is done to equipment or personnel and to insure that all is in proper condition for firing.
2.	See that igniter burner cocks and main burner three-way cocks are closed so that air pressure can pass through all eight cocks to the pressure switch.	Turbine operator	All these cocks must be in closed position in order for air pressure to get to the pressure switch. The pressure switch must be closed before the timer will start and make electricity available to the solenoid of the main gas shutoff valve and the igniter solenoid valve. This setup requires that the cocks be in closed position before the timer operation will strat.
3.	See that the Bailey gas control valve is in the closed position.	S & P operator Turbine operator	The control air pressure to the diaphragm of the main gas control valve also goes to a pressure switch. This switch must be closed before the timer will start and make electricity available to the solenoid of the main gas shutoff valve and the igniter solenoid valve. This switch is closed at "O" pressure. The main gas control valve is closed at "O" pressure. This setup requires that the main gas control valve be in closed position before timer will start.
4.	See that the gas pressure in main supply line coming to the boiler is not over 30 p.s.i.g.	Turbine operator	A "high pressure" switch measures the pressure of the gas in the main line to the boiler. It will open the electrical contacts, if gas pressure is over 30 p.s.i.g. The pressure switch must be closed before the timer will start.
5.	Start the i.d. fan following normal startup procedure.	S & P operator Auxilliary operator	The trip mechanism of the i.d. fan turbine closes the electrical contacts of a limit switch when in the reset or "turbine running" position. This switch must be closed showing that the turbine is running, before the timer will start.
6.	Etc.		

TRAINING FOLLOW-UP AND REQUALIFICATION

As a follow up to our training programs, we have requalification sessions with each man once a year. The man attends a conference with me, our training director, and other members of our engineering group. The man is asked questions about various phases of his job to see that first he knows and, second, has no wrong understanding of any piece of equipment or operation. He is also given a chance to ask us questions and to make suggestions on what he thinks would improve our training programs.

DOES THE PROGRAM WORK

Does the program work? Is it effective? How can we tell?

The best gage of training, we feel, is operator response to emergency situations. As in every industry we have had our share of emergencies—and our operators have worked smoothly and efficiently as a team each time. Take these two examples, for instance:

1. We lost both of our natural gas fired power boilers 12 times during this past winter due to gas pressure failures. Prompt and correct action by all operators working as a team prevented interruption of production.

2. Our power plant electric service was interrupted when a high voltage cable shorted out. Teamwork and immediate action by our operators avoided serious damage to equipment and we were back in operation within a short time through temporary wiring.

In conclusion, we have learned that training is a vital part of all phases of our business at Buckeye. I am sure you will agree that the future of our business, as well as yours, depends a great deal on proper training

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

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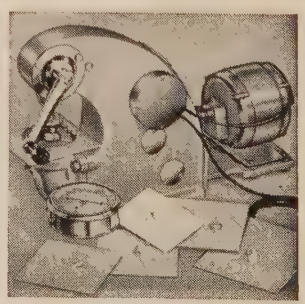

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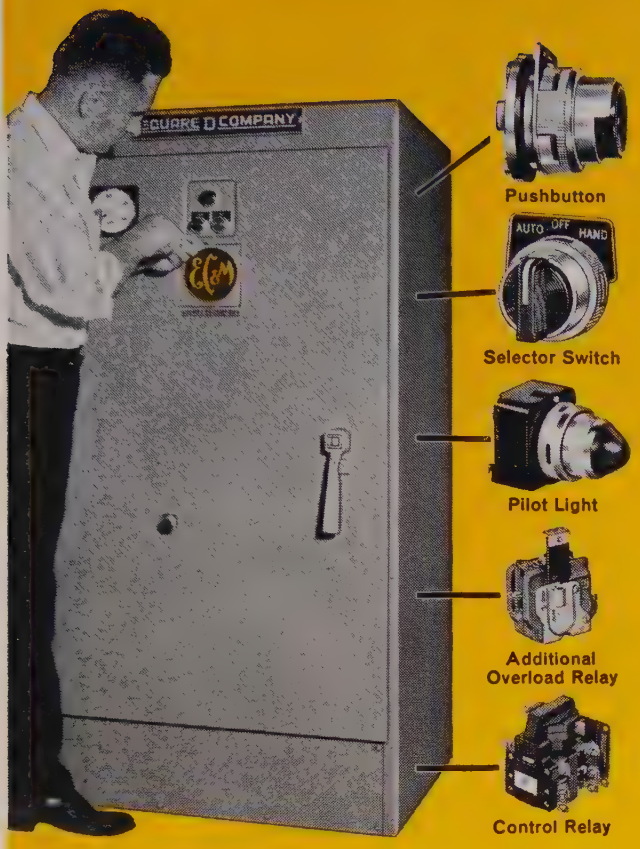

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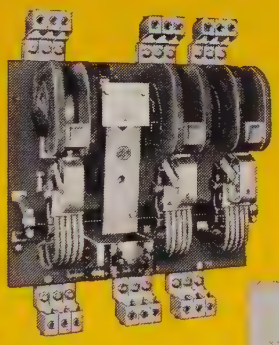
Square D NEMA Size 6, 7 and 8 magnetic starters are now built with a plate in the door to accommodate modifications when needed. The same modifications which have long been available on Square D starters through Size 5—pushbuttons, selector switches, pilot lights, additional overload relays, auxiliary contacts—can now be added to the larger starters without special engineering.

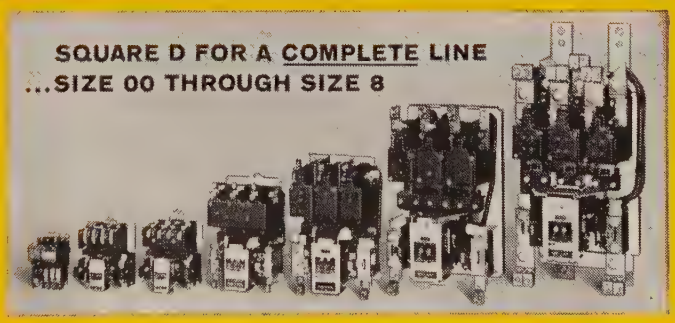
This means fast processing of your order, quick delivery of your starters. What's more, you can make the same modifications in the field. The wiring diagram shipped with each starter shows exactly how to do it.

Available in ratings up to 900 hp, Square D Size 6, 7 and 8 starters can be ordered as open devices, or in general purpose, dust-tight and water-tight enclosures.

• With Square D Size 6, 7 and 8 starters, you get DC-operated (self-contained DC supply) mill-type contactors—at no extra cost. Exclusive Line-Arc construction dissipates heat, provides longer contact life. Self-lubricating bearings plus simple design make maintenance extremely easy. Another standard feature is lugs which accommodate either copper or aluminum cable.



• The magnetic starters shown at right—which range from Size 00 through Size 5—plus the Size 6, 7 and 8 starters described above, add up to a *complete* Square D line for *any* AC motor application.



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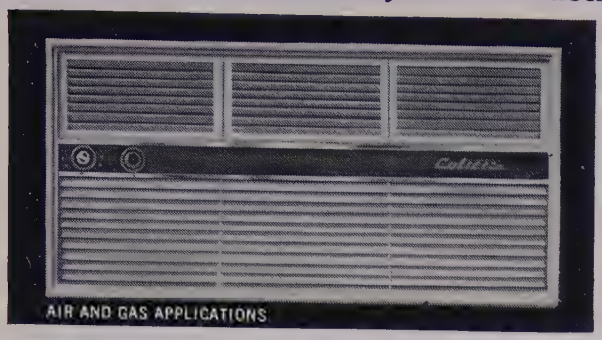
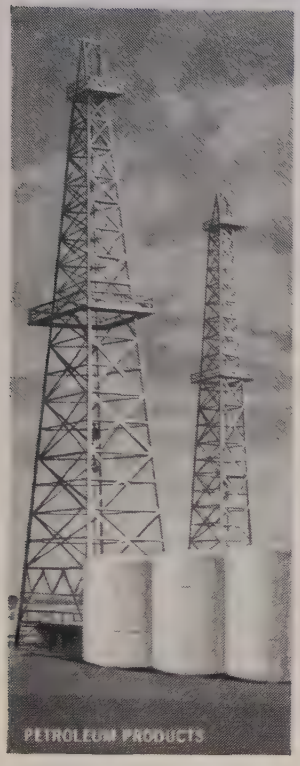
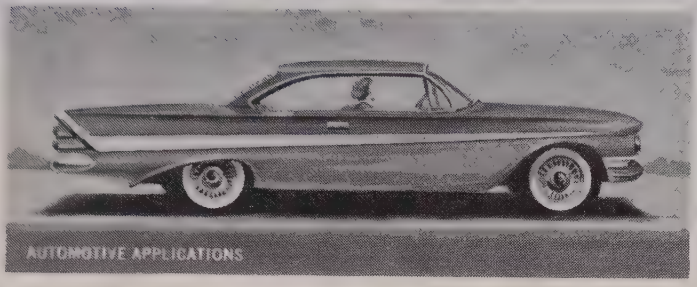
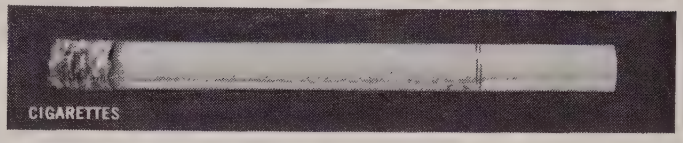
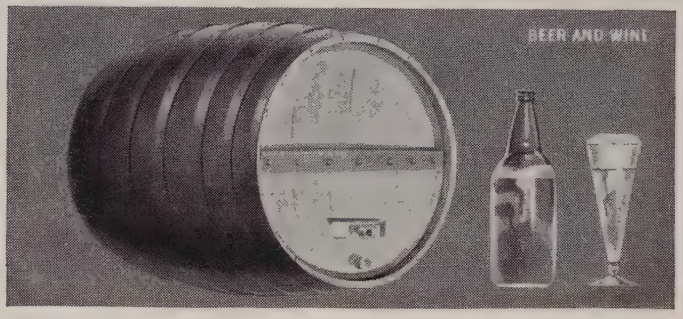










What do you want to filter better?

Many people who make or use filters are discovering that they can do a better job of filtering for less money with filters of Avisco® rayon. The diameter of man-made Avisco rayon fibers is so closely maintained that filter micron ratings can be held to meet most filtration specifications. So, whether you're interested in the filtering of liquid foods, oils, air, lacquers, paints, smoke, water, liquors or lotions—whether you are manufacturing filters by the wet or dry system—look into Avisco rayon fibers. Fill out and mail in the Quick Reply Coupon.

QUICK REPLY COUPON 7-7

Industrial Merchandising Division
American Viscose Corporation
350 Fifth Avenue, New York 1, N.Y.

Please contact me about Avisco Rayons for use in the following application:_____

Name_____

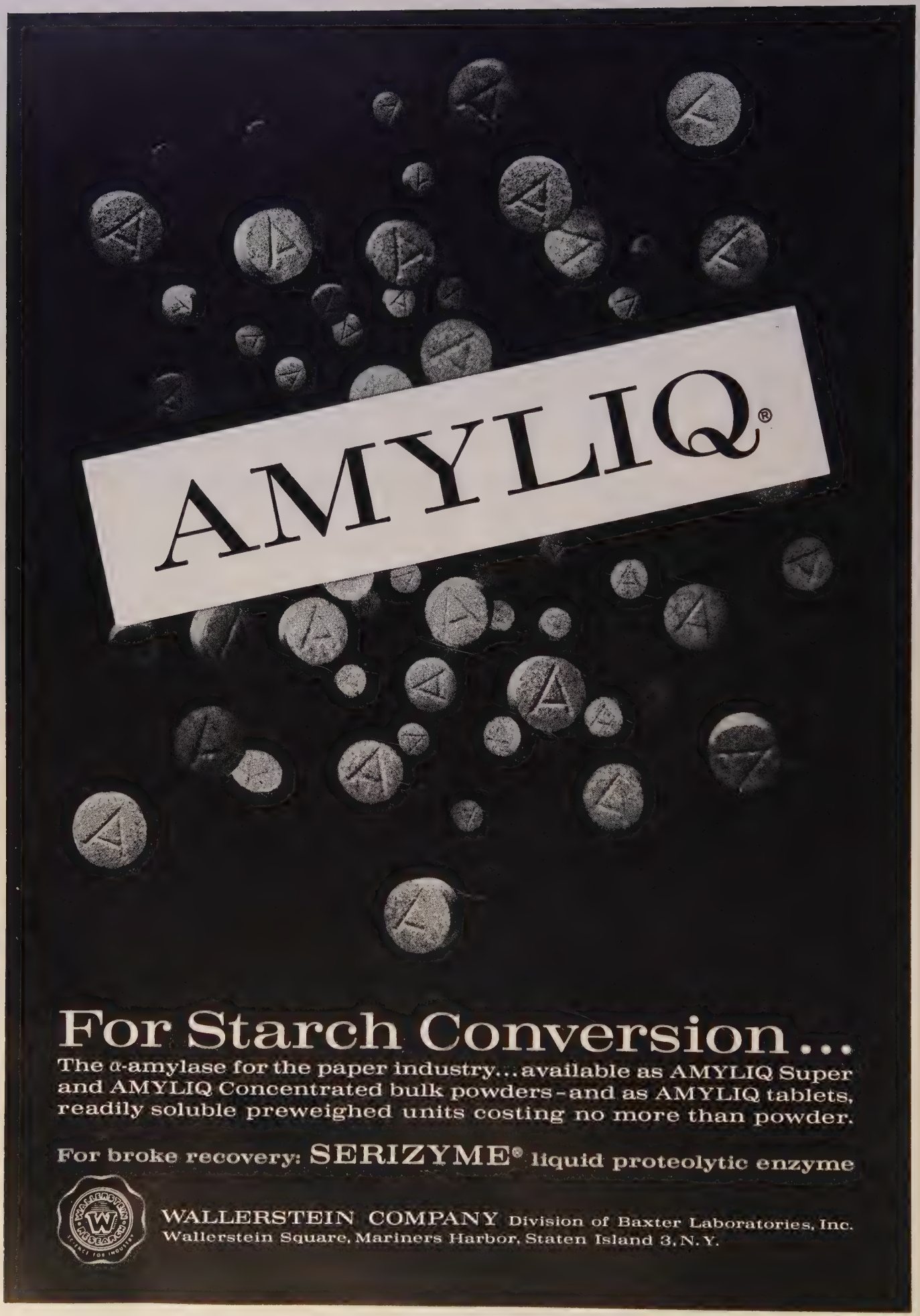
Company_____

Address_____

City_____ Zone____ State_____

AVISCO® RAYON

AMERICAN VISCOSE CORPORATION, 350 Fifth Avenue, New York 1, N.Y.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The α-amylase for the paper industry... available as AMYLIQ Super and AMYLIQ Concentrated bulk powders - and as AMYLIQ tablets, readily soluble preweighed units costing no more than powder.
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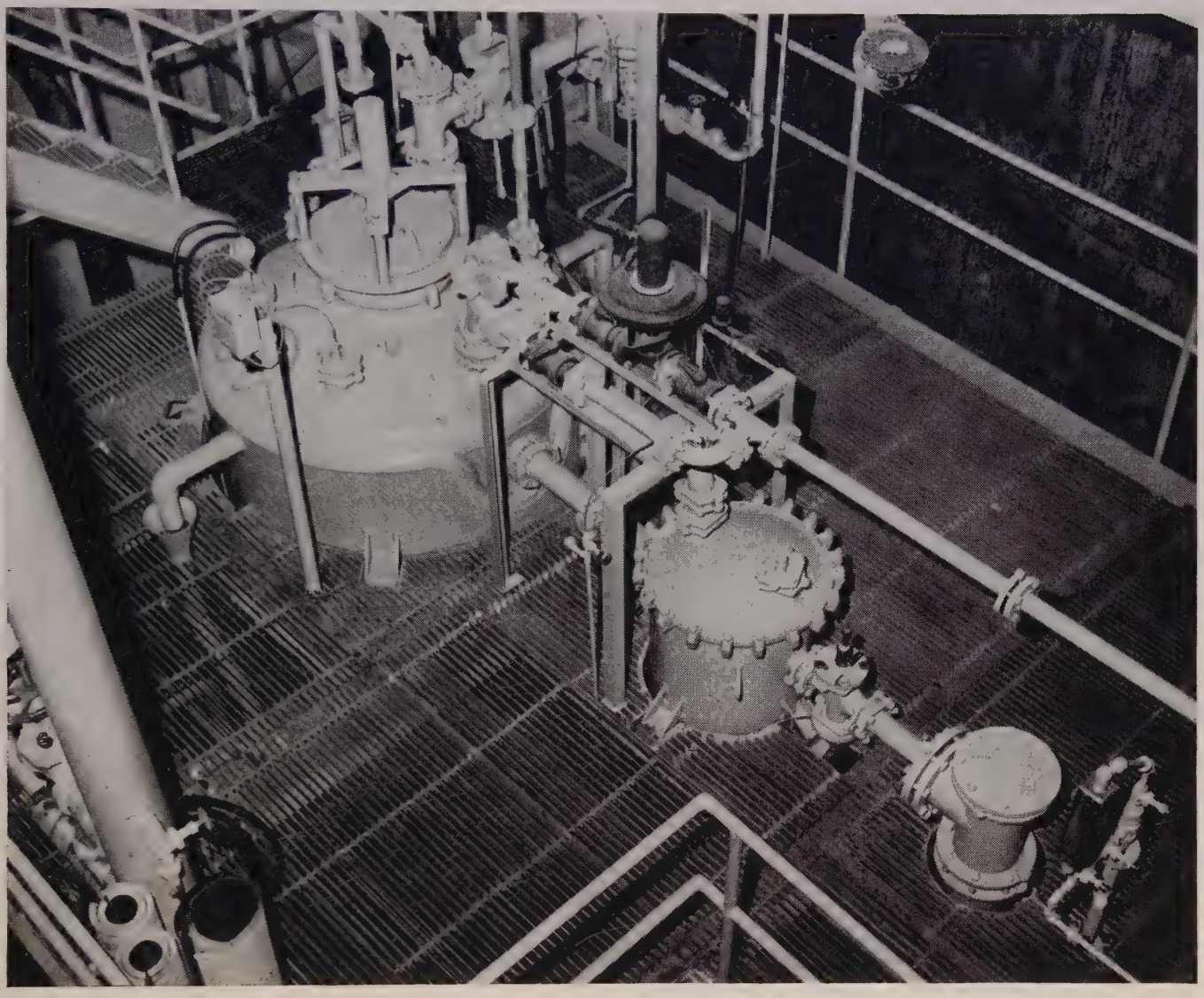
WALLERSTEIN COMPANY Division of Baxter Laboratories, Inc.
Wallerstein Square, Mariners Harbor, Staten Island 3, N. Y.

FLUIDICS* AT WORK



Tell us your ClO_2 requirements ...we'll take it from there

If you're contemplating the construction or expansion of a chlorine dioxide generating system, now is a good time to contact the Pfaudler Project Engineering group.

This is a *service* group—set up to provide a *temporary* addition to your engineering staff.

Starting with your data and process, we can come up with an integrated design to achieve the required operations and controls.

You can call on our Project Engineering service for *any or all* of these functions: (1) Design of system or plant. (2) Selection and specification of equipment. (3) Layout. (4) Procurement and expediting of equipment. (5) Contracting for erection. (6) Start-up assistance and personnel training.

Corrosion resistance. In ClO_2 generating equipment, we offer the basic components fabricated from Pfaudler® Glasteel. This gives you an unmatched combination of materials—*glass* inside for complete corrosion protection, *steel* outside for working strength.

If you desire, we can provide the entire "package"—primary and secondary generators; storage for chlorate, chlorine dioxide, chemicals, and waste liquors; scrubber, absorber, and stripper columns; pumps; piping; and instrumentation.

More details. One excellent example of Pfaudler Project Engineering and equipment in action is the plant (pictured above) at Gaspesia Sulphite Company, Ltd., Chandler, Quebec. It's described in Reprint No. 535. For your copy, or answers to questions about how we can best serve your ClO_2 needs, write to our Pfaudler Division, Dept. TA-31, Rochester 3, New York.

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Specialists in FLUIDICS . . . the science of fluid processes

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

Wet strength whenever your paper demands it

You get double usefulness from Rohm & Haas UFORMITE® wet strength resins. They're tailored for highest performance in your end product, and they also give you important processing advantages.

There's a UFORMITE that's just right for toweling, napkins, bag paper, butchers' wrap, paperboard, or your specialty items. And you can expect excellent storage stability, ease of handling—no acid pretreatments needed—and easy broke recovery.

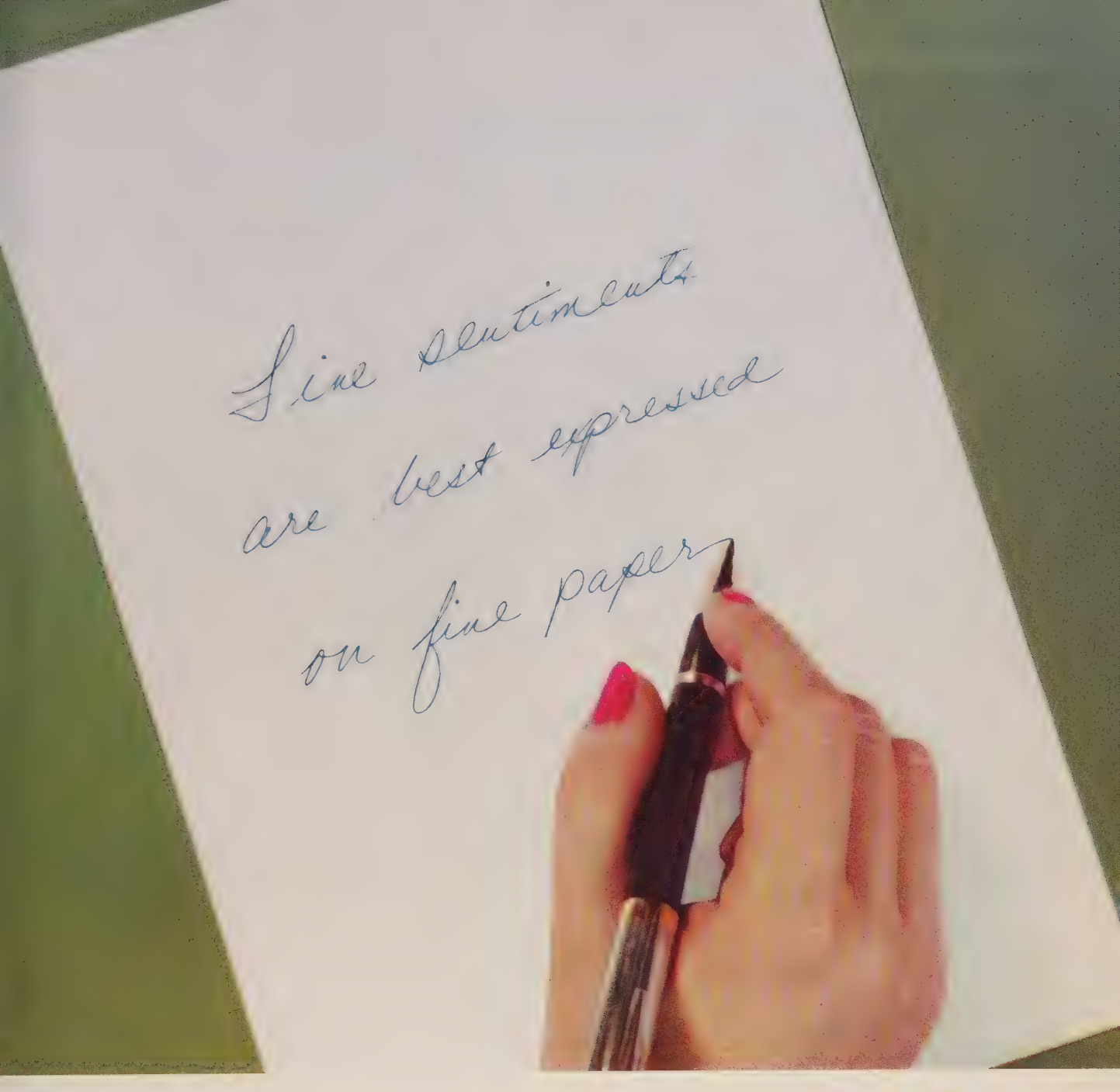
Choose UFORMITE 700 for high off-the-machine wet strength without the broke problems this would normally cause. Choose UFORMITE 711 for good all-round performance at low cost. Choose UFORMITE 467 for economy on unbleached papers.

Complete technical information on UFORMITE resins will be sent on request. Ask for the booklet, UFORMITE Resins for Wet Strength Paper.

ROHM & HAAS

PHILADELPHIA 5, PA.

UFORMITE



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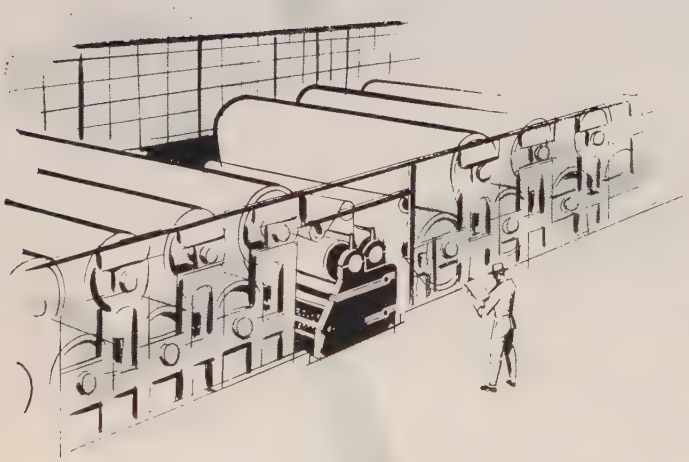

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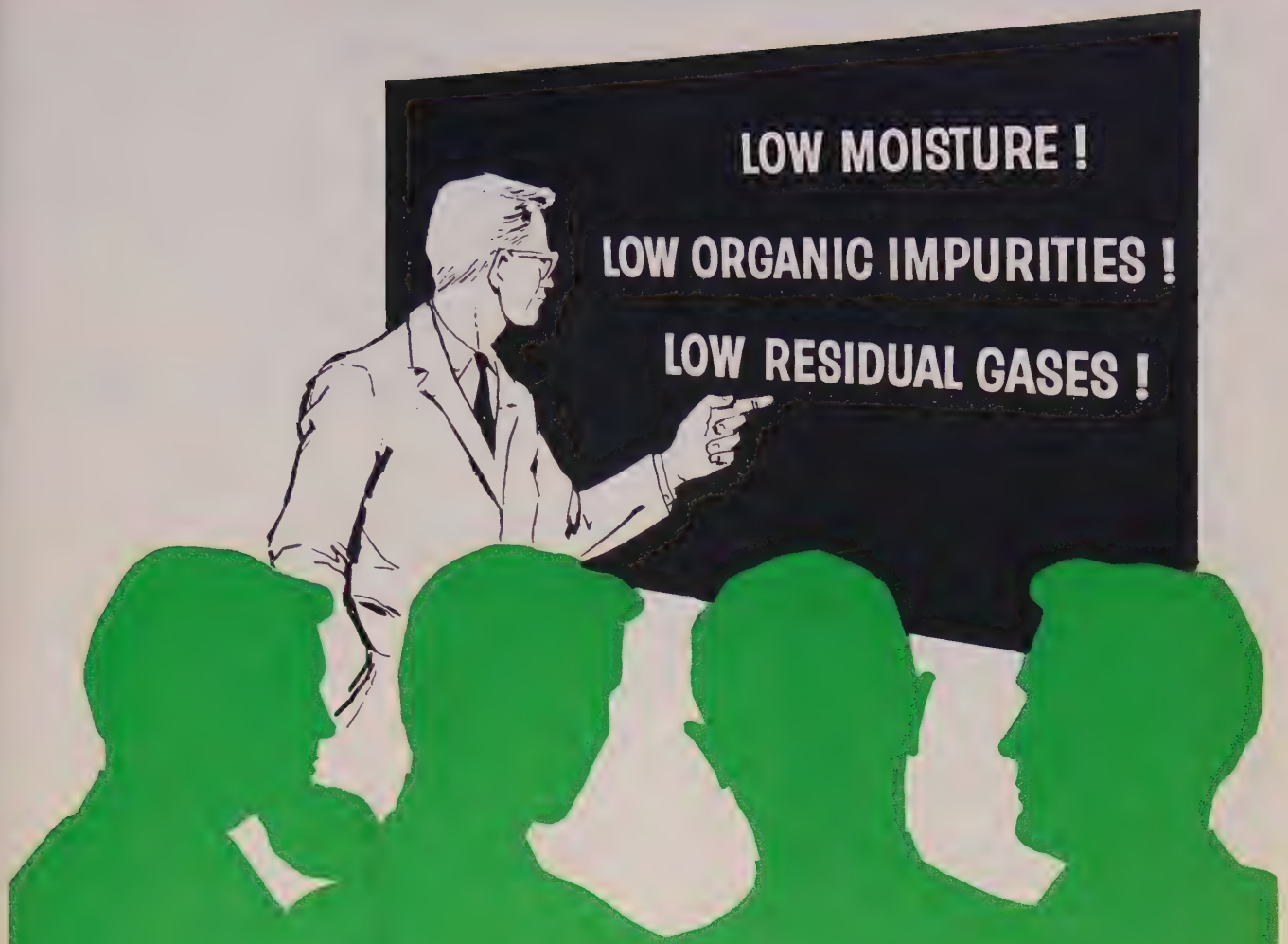

low-down on fmc CHLORINE

Reason for this unexcelled purity? FMC Chlorine is produced in the most modern new cells under the watchful eyes of the latest fully-automatic quality controls.

Our South Charleston, West Virginia plant is ideally located for fast dependable service to industrial areas of the East, Northeast, Midwest and mid-South. We will welcome an opportunity to discuss our ability to supply a share of your future requirements.

Putting Ideas to Work

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Chlor-Alkali Division
General Sales Offices:
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*Idea submitted by William A. Steadwell, St. Regis Paper Co., Jacksonville, Florida

Photo by: Louis C. Williams, Nashville, Tenn.

Known as "Split Rock" Lighthouse.

HAM FELTZ says:

"Reminds me of HAMILTON Felts... always reliable!"

"Navigators on Lake Superior
look to Eagle Rock Light House
for the same reason many papermakers
look to Hamilton Felts . . .
reliability.

"The reliability that characterizes
Hamilton Felts is the result of
our traditional code of proud craftsmanship,
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of technical improvement.

"So if *you* want felts
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consistent, high quality performance,
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look to Hamilton Felts.

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technically proved patterns
won't solve *your* specific problem,
we'll be happy to design
a Hamilton Felt that will.
Just ask your Hamilton Felts Service Salesman."

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"What famous place reminds you of Hamilton Felts? Tell us why in a few words; sign your name and address and name of company. . . Each idea from a U.S. papermaker that we use wins a new 1961 model Shakespeare Spincast Rod and Reel—FREE! When identical winning ideas are submitted by 2 or more papermakers, the one with the earliest postmark will be considered the winner. Every U.S. papermaker *entrant* receives a famous Rex Spoon fishing lure—FREE. Send me your suggestion—today. Ham Feltz, Dept. T, 612 First Natl. Bank Bldg., Cincinnati 2, Ohio."

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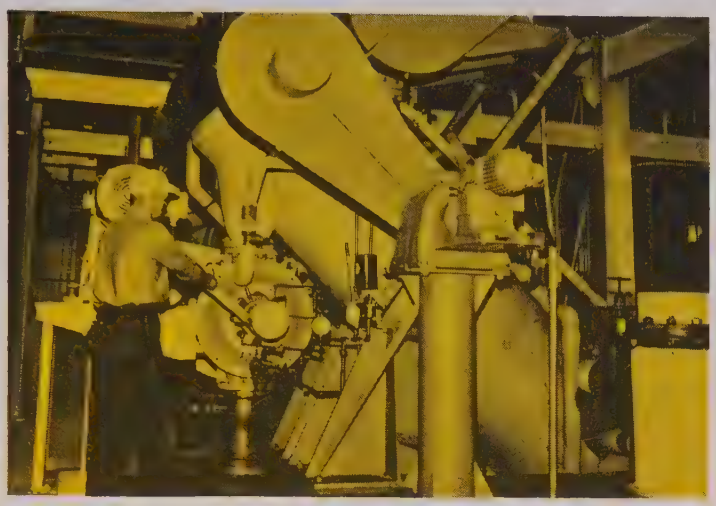
SHULER & BENNINGHOFEN, HAMILTON, OHIO

3 Types of Automatic Digesters To Increase Mill Capacity

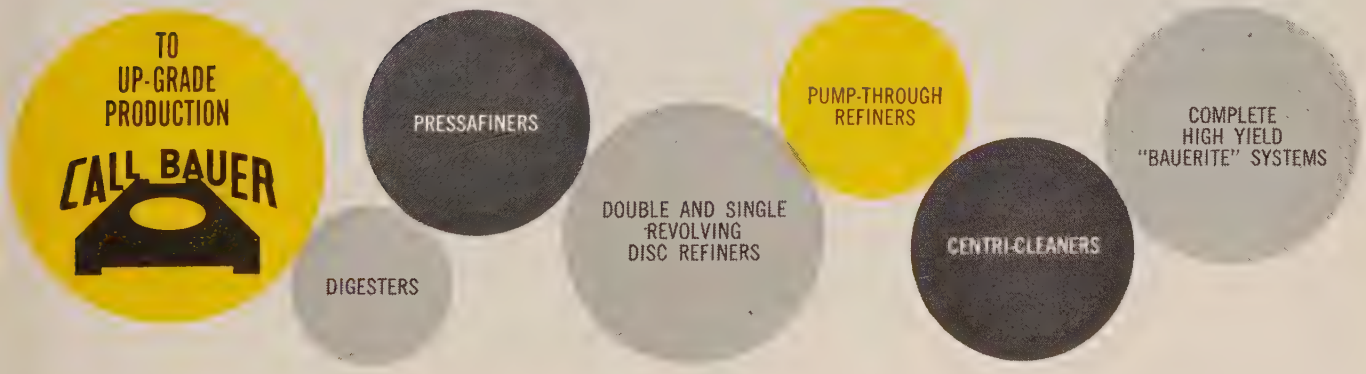


M & D Continuous Digester.
Note inlet and discharge valve are on same floor level.

M & D DIGESTER (continuous) — Inclined tube type... makes controlled continuous digestion of chips practical. Suitable for wide variety of end products as units are engineered to your requirements. Completely automatic; reduces labor costs, improves uniformity. 90% of unit can be outdoors.

RAPID CYCLE DIGESTER (batch) — Fast, automatically controlled batch cooking... high temperatures and pressures (up to 300 psi) reduce cooking time to minutes. For any type pulp and flexibility in procedures... ideal for multiple treatment—presteam, impregnate, vapor phase. Compact... easy to install. Stainless steel... no lining... long life.

GRENCO DIGESTER (continuous, vapor phase) — Most economical for vapor phase method of preparing wood chips... automatically controlled... simple in design. To increase output units can be "stacked." Automatic... continuous feeding and discharging... minimum space requirement... relatively light weight.



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Springfield, Ohio

IN CANADA: THE BAUER BROS. CO. (CANADA) LTD.
Brantford, Ontario

AMRES 212
AMRES 8850

Why more than 20 major Pacific Coast mills insure wet strength performance with American-Marietta resins

The west's leading producers manufacture wet strength papers for everything from containers to facial tissue. When it comes to wet strength resin selection, these mill men choose American-Marietta's AMRES 212 or 8850 *more than all other available resins combined!*

This kind of confidence wasn't built overnight. For more than a decade western resin buyers have depended on American-Marietta research to develop reliable products to keep pace with the demands of a growing industry. With key A-M technical service personnel always available, paper manufacturers know that they can tackle new production problems backed by experienced, mill-seasoned men.

Nearly every major Pacific coast paper processor relies on fast, efficient American-Marietta service to handle wet strength needs. Carefully controlled quality and a wide selection of urea-, phenol-, and melamine-formaldehyde and neutral curing resins insure that they are supplied with versatile products which perform consistently in a host of applications.

These same product-service advantages have been made available to paper manufacturers in Wisconsin. Ask for the A-M Fact File detailing products and services. Write today!

AMERICAN-MARIETTA COMPANY
Adhesive, Resin and Chemical Division

NEWARK, OHIO
42 South Third Street

SEATTLE, WASHINGTON
3400 13th Avenue S.W.

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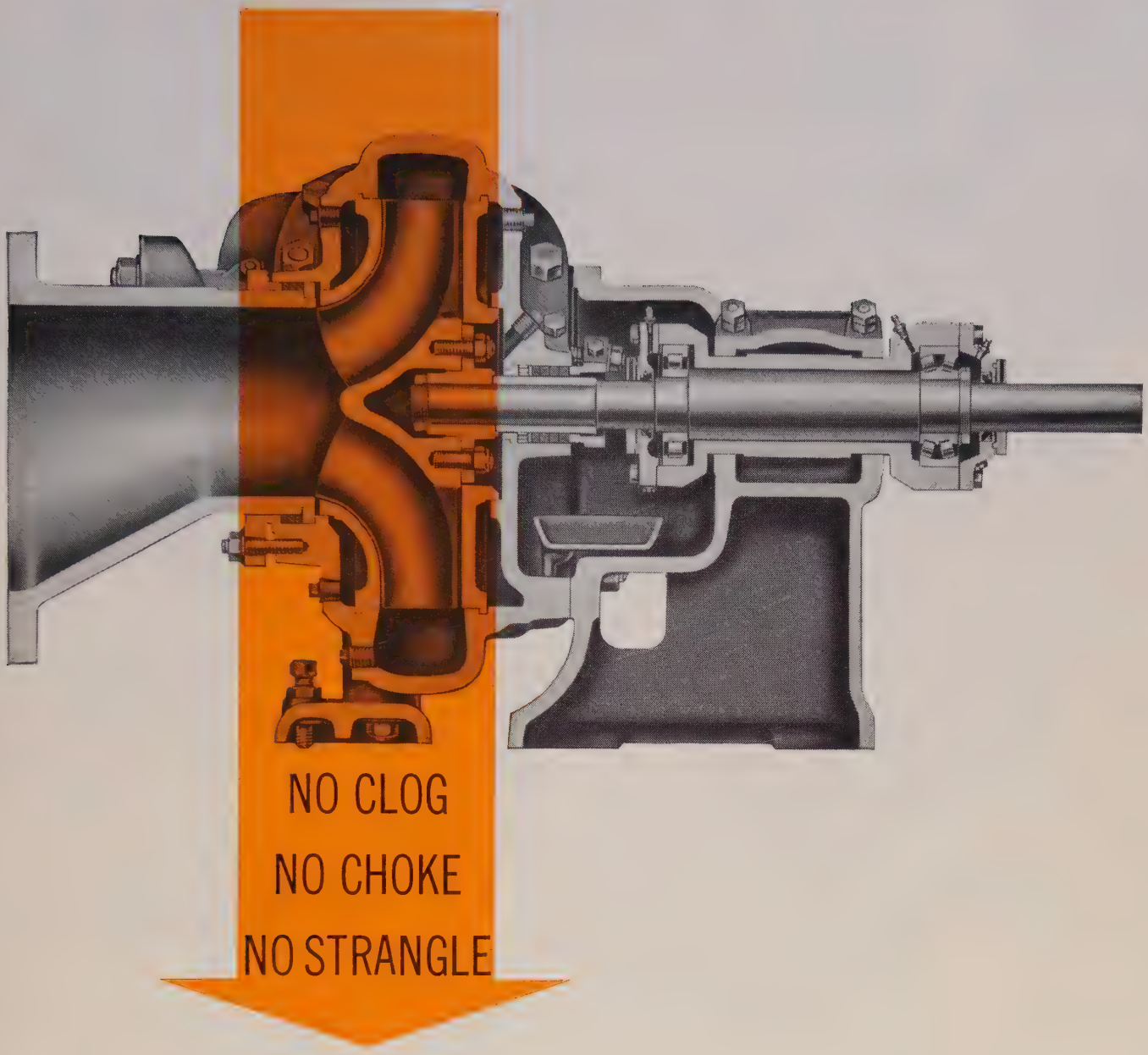


This pump swallows paper stock whole

Its impeller shows you why.

The Model 3135 has an open, end suction, non-clogging impeller. Stock flows easily into its big eye, pushed along by inlet vane tips, warped to give a screw conveyor effect. The warped vanes also prevent water separation of stock, without supplemental feeding mechanisms.

Nothing catches at the eye—no fibres, strings, or other material—because there is no nut or other obstruction there. Internal lock nuts hold the impeller to the shaft flange.

Stock can't jam between the back impeller wall and the stationary side plate since both ejector and main vanes follow the same curve.

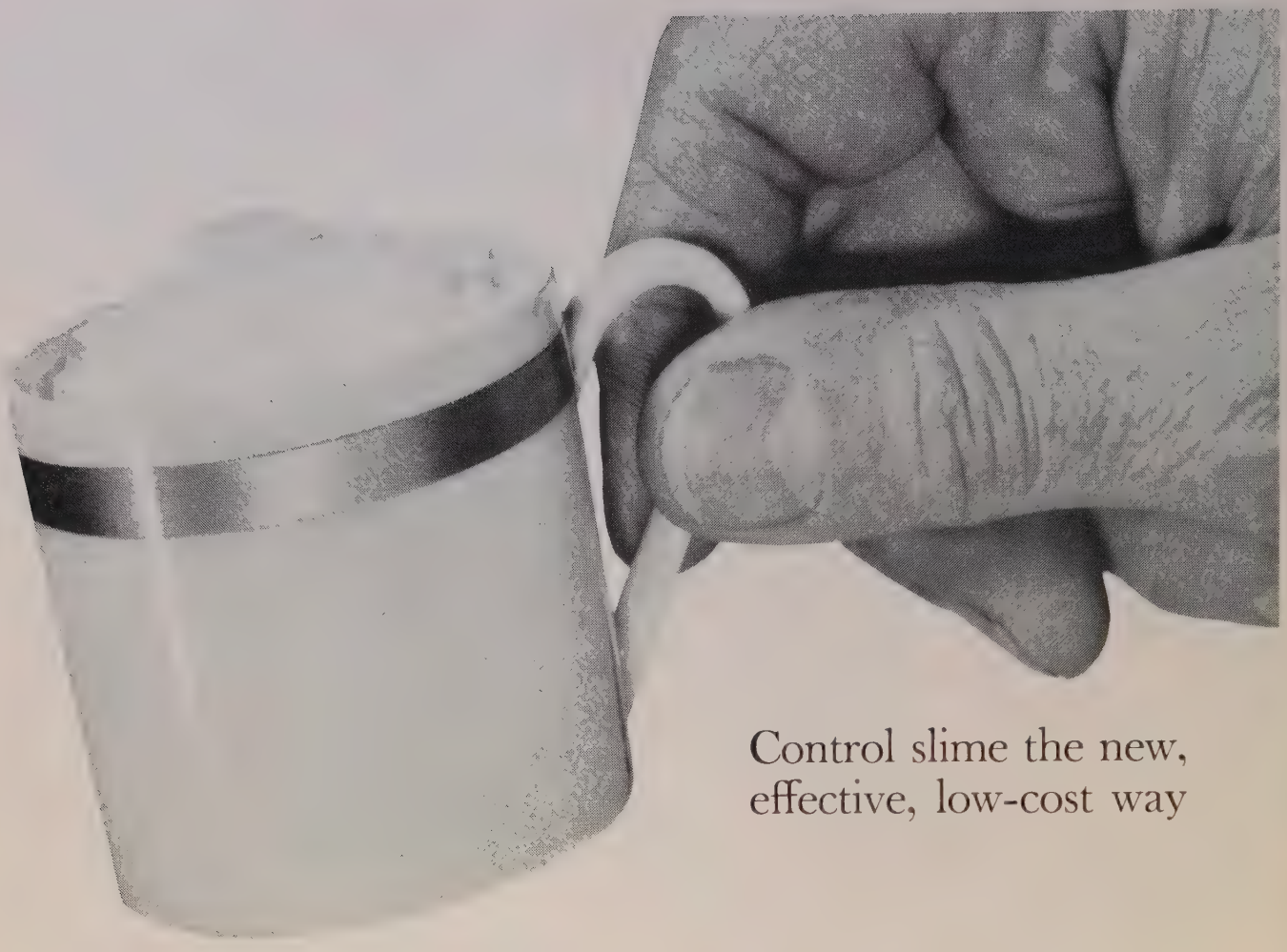
Longer packing life. Pump-out vanes on the impeller back also reduce pressure on the stuffing box for a greatly extended packing life.

Restore clearance easily. When wear occurs between impeller and suction side plate, simple external adjustment moves shaft and impeller axially towards suction side plate.

Free bulletin gives performance curves of Model 3135, an illustrated step-by-step description of the fast removal of the rotating element, specifications, and other useful information. Ask for Bulletin 723.1.

Goulds Pumps, Inc., Dept. TA-31, Seneca Falls, New York.

GOULDS PUMPS



Control slime the new, effective, low-cost way

Just this much C2® slimicide for a ton of pulp!

- Newsprint
- Unbleached, semi-bleached and bleached kraft
- Food and paper board
- Printing and book papers

EFFECTIVE. Extensive mill use proves conclusively that C2, the new Mathieson slimicide, is the most effective product for acidic white water systems. Only ¼ pound of C2 per ton of pulp (often even less) is a common dosage rate for rapid, sustained control. Actual cost per ton: about 10-20¢. Resultant action: continuous generation of chlorine dioxide throughout the white water system . . . a distinct advantage over other slimicides which function only near point of application.

Other C2 advantages: no foaming at the head box . . . will not darken pulp . . . will not affect dyes at recommended dosage rates.

EASY-TO-USE. C2 is readily soluble in water and is non-corrosive to equipment.

C2 is shipped in highly-soluble, dry-flake form in quantities from one-pound samples to 100-pound drums in truckloads and carloads. Also, 50% solution is supplied in tank cars and trucks.

FDA CLEARANCE. C2 is our trademark for sodium chlorite. The Food And Drug Administration has expressed the opinion that this chemical is not a food additive when used as a slimicide as it cannot reasonably be expected to become a component of food through this use.

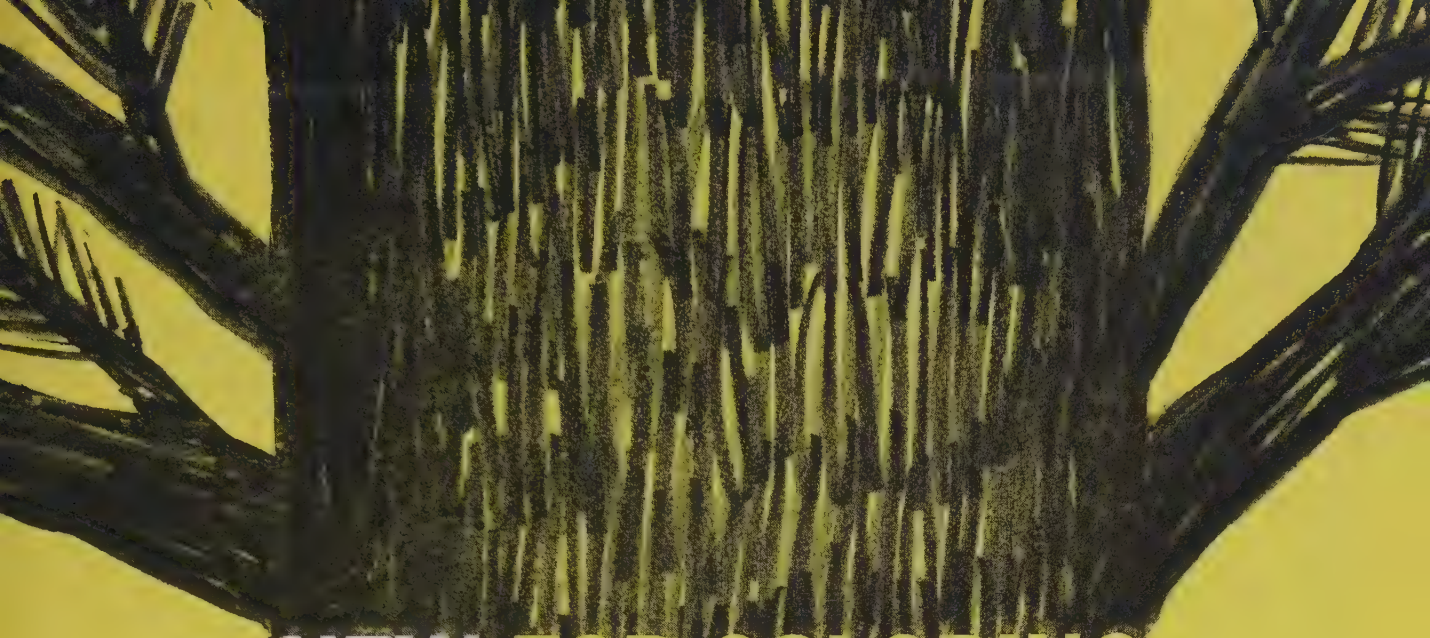
See C2 work in your mill—call for a demonstration.

Olin Mathieson

C2® is a trademark.

Chemicals Division, Baltimore 3, Maryland

8922



NEW—FOR COLORING PAPER IN THE PULP

STILBENE YELLOW 10 GP

Sized papers gain a premium look at budget prices

Dye lively canary and green shades with economy and satisfaction.

Reduce costs to new lows for bright yellows on commercial grades of bond, register, tissues, and wrapping papers. See the excellent color value and dyeing properties—light fastness comparable to other Stilbene Yellow types—nondusting.

Inquire how you can profit with this new direct dye and other GDC Stilbene Yellows in meeting your color requirements on sized papers.

Ask about—

STILBENE YELLOW TP CONC	economical reddish yellow
STILBENE YELLOW 3 GA CONC CF	slightly greener than Yellow TP Conc
STILBENE YELLOW 5 GXA	greener, brighter than Yellow 3 GA Conc CF
STILBENE YELLOW 6 GP	greener, brighter than Yellow 5 GXA
STILBENE YELLOW 8 GP	greener, brighter than Yellow 6 GP
DIRECT YELLOW CPA CONC	alkali-fast Stilbene types:
DIRECT YELLOW OPN	balancing colors for Paper Yellow 3 GXA

Call your GDC Technical Service Representative for complete information and samples or write us direct.

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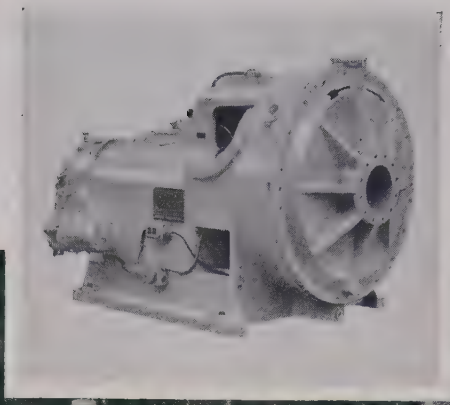
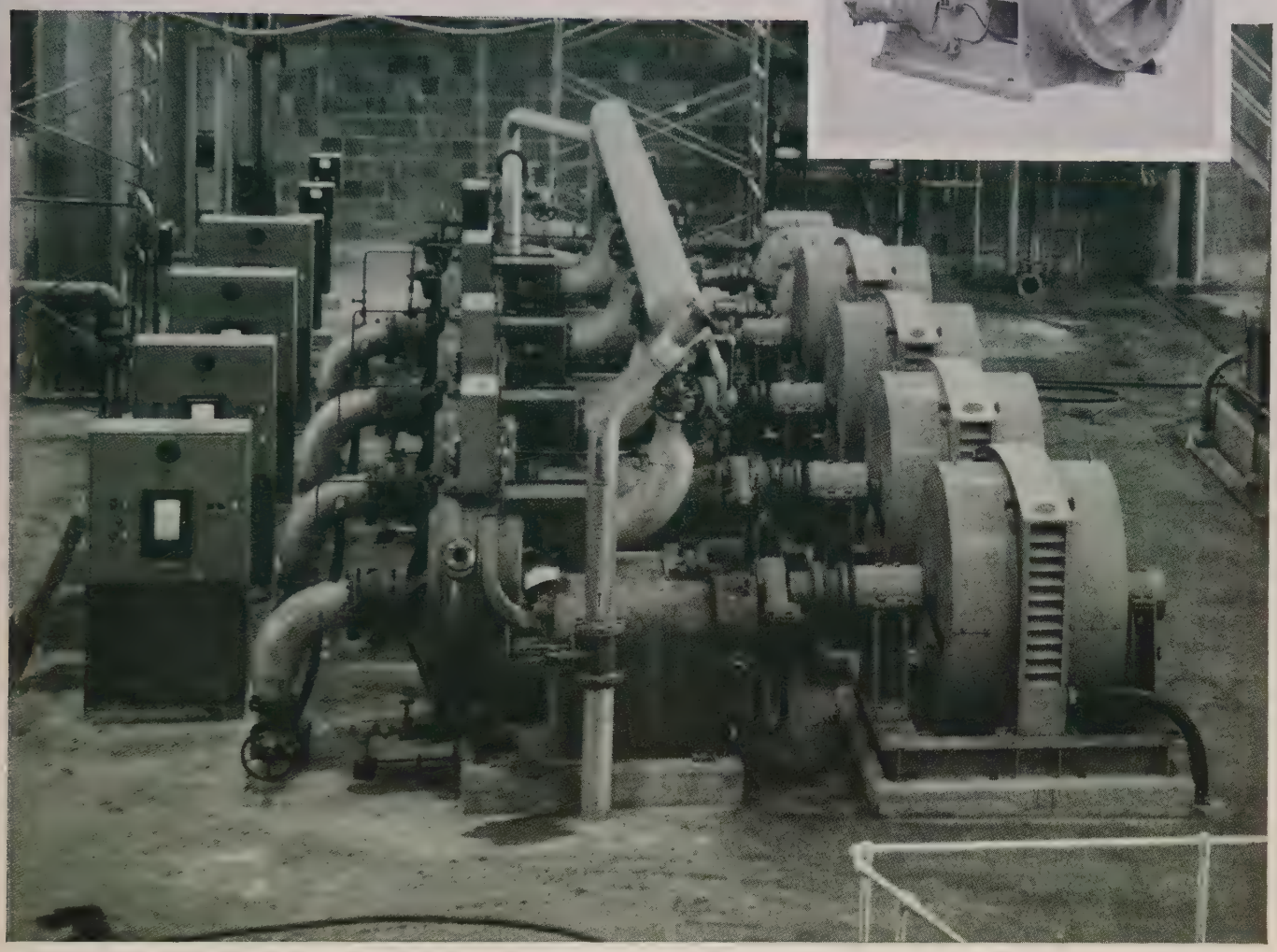
Only 4.4 HP days per ton Used by Jones Double-D's

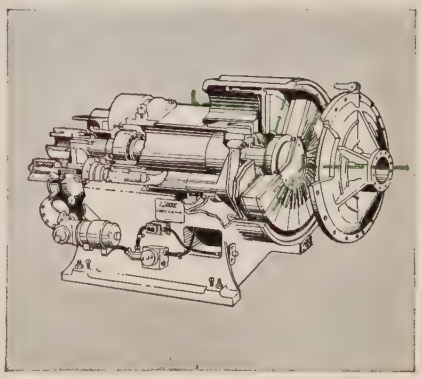




. . . at International's Pine Bluff Mill

Production schedules at International's Pine Bluff Mill call for over 500 tons of quality foodboard stock per day — from one 300″ Beloit machine. Helping to make this tonnage possible is an efficient battery of four Jones Double-D's operating in parallel for primary refining. Each unit is driven by a 600 HP motor. Working continuously since the mill was put in operation, *each Double-D has been processing approximately 140 tons per day . . . for an outstanding performance rating of only 4.4 HP days per ton* to accomplish almost two thirds of the total primary refining. Important, too, is the fact that Jones Double-D's save on floor space — since each does the work of two ordinary single disc machines.

The experience at International is typical of Jones Double-D's efficiency in many mills. Why not get high production at low HP days per ton — with less floor space in your mills, too? For full details write to E. D. Jones Corporation, Pittsfield, Massachusetts, for Bulletin EDJ-1083.



With Jones Double-D's, stock under pressure passes between two single-faced stationary discs and one (center) double-faced rotating disc. This results in precision controlled two stage refining.

E. D. JONES CORP. PITTSFIELD, MASS. BELOIT group

Jones

PULP MILL EQUIPMENT AND STOCK PREPARATION MACHINERY

Canadian Associates:
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75 Spencer St., Ottawa

Give your coated paper improved wet rub resistance!

In today's offset printing process, wet rub resistance is necessary to avoid cloudy inks and muddy colors. The addition of new DYLEX® K-54 latex in your offset coatings will give your paper improved wet rub resistance. The rubbing of the wet blanket won't fade inks or remove the coating. With this exceptional latex, your full color pages will reproduce clear and bright. ☐ Along with improved printability, paper coated with DYLEX K-54 has a higher degree of smoothness, superior bonding strength, and increased pick resistance. New DYLEX K-54 is easy to apply, foams less, and blends well with other paper coating additives. ☐ Learn how DYLEX K-54 can upgrade your coated papers. For more information on any of the new series of DYLEX latices for paper coatings write Koppers Company, Inc., Plastics Division, Dept. 2503, Pittsburgh 19, Pennsylvania.

KOPPERS PLASTICS KOPPERS

Only MANHATTAN RUBBER COVERED ROLLS

Assure ALL These Performance Advantages

- Uniform Squeeze . . . Sure Release
- No Pick-up . . . No Crush
- Longer Felt Life
- Won't Crack, Corrugate or Oxidize
- More Water Removal— at Lower Dryer Steam Costs
- High Machine Speeds . . . Lower Production Costs
- Require Minimum Regrinding—Even Under Extreme Conditions of Use

Advanced roll covering facilities and skilled craftsmanship at Manhattan make the difference. Manhattan's inseparable rubber-to-metal bond eliminates cover separation. Manhattan's grinding and vulcanizing facilities insure uniform, exact density—and accuracy of crown dimensions within .002″. Manhattan's electronic balancing of rolls—at *your* machine speeds—guarantee *uniform* pressure and moisture distribution in the stock . . . less wear on felts, bearings and journals.

GET "MORE USE PER DOLLAR" ON EVERY CRITICAL ROLL FUNCTION WITH THESE MANHATTAN RUBBER COVERED ROLLS.

• Press Rolls—Ray-Roc, Rub-Roc, Sham-Roc, Self-Skinner • Suction Press and Coating Rolls • Sealed-End Couch Rolls • Marblex Table Rolls

Facilities near you . . .

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MANHATTAN RUBBER DIVISION • PASSAIC, N. J.

ENGINEERED RUBBER PRODUCTS

RM136

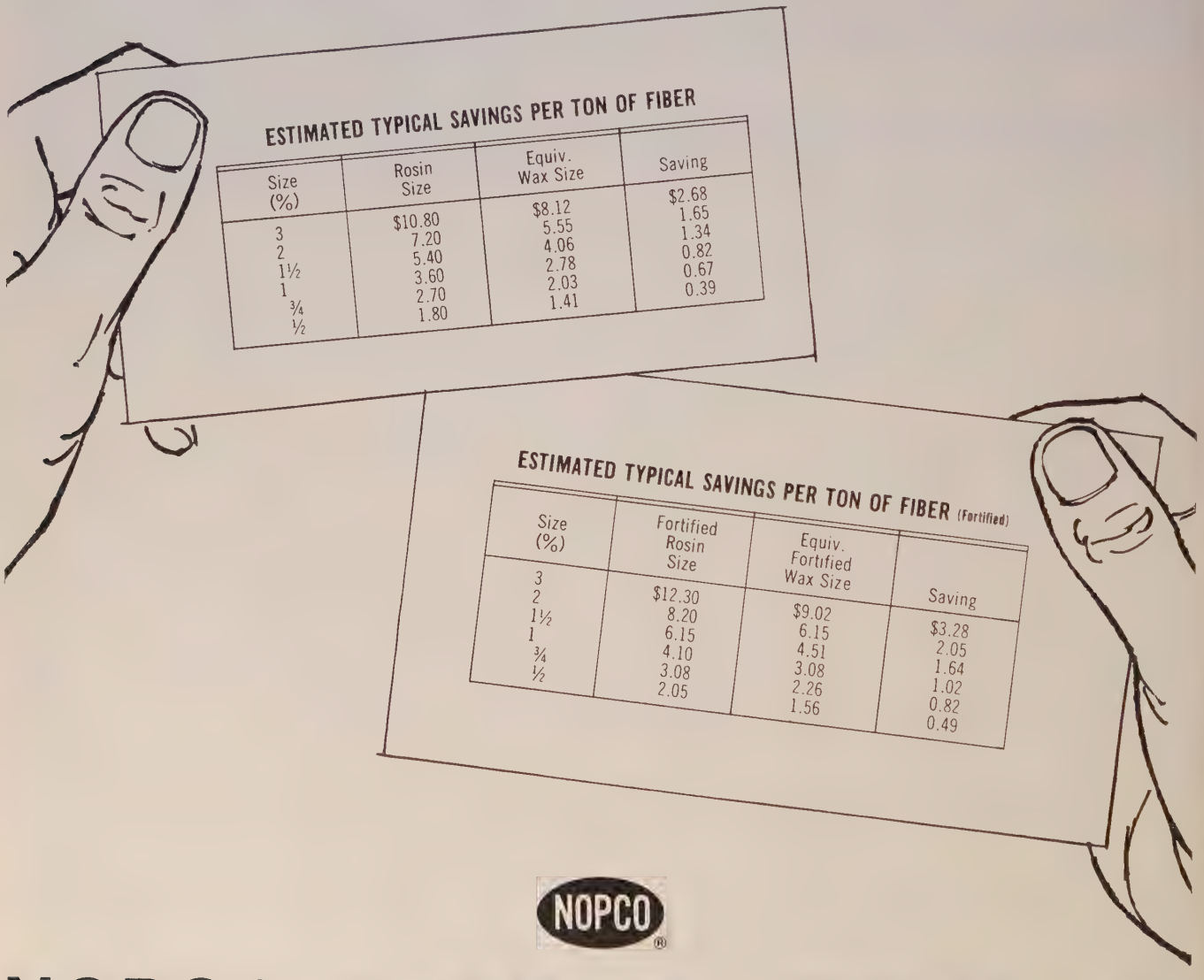
Are your rosin size costs too high?

Nopco® Wax Sizes do more—cost less

Whether your mill uses rosin or fortified-rosin sizes, Nopco can show you how to reduce your sizing costs by using its wax sizes. In addition to saving you money, Nopco Wax Sizes impart improved resistance toward water, ink, lactic acid, alkalis and blood; improve gloss, smoothness and printability; and decreases fuzz, curl and brittleness.

Use of Nopco Wax Sizes in your mill is an advantage you cannot afford to overlook. Let us help you set up a program of tests and trial runs to prove it to your own satisfaction.

Our Technical Service Engineers, utilizing over 30 years' experience with wax sizes, are ready to show you the advantages to be gained by the use of wax sizes in conjunction with rosin sizes. Write today for further information.



ESTIMATED TYPICAL SAVINGS PER TON OF FIBER

Size (%)	Rosin Size	Equiv. Wax Size	Saving
3	$10.80	$8.12	$2.68
2	7.20	5.55	1.65
1½	5.40	4.06	1.34
1	3.60	2.78	0.82
¾	2.70	2.03	0.67
½	1.80	1.41	0.39

ESTIMATED TYPICAL SAVINGS PER TON OF FIBER (Fortified)

Size (%)	Fortified Rosin Size	Equiv. Fortified Wax Size	Saving
3	$12.30	$9.02	$3.28
2	8.20	6.15	2.05
1½	6.15	4.51	1.64
1	4.10	3.08	1.02
¾	3.08	2.26	0.82
½	2.05	1.56	0.49

NOPCO®

NOPCO CHEMICAL COMPANY

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Manufacturing Licensees Throughout the World

ideas and news

One-man maintenance for new vertical pump: This redesigned A-C pump gives quick access to internal parts. One mechanic can remove entire rotating element without need of an electrician to disconnect the motors or a pipe fitter to break piping. In addition, vertical design takes 25% less floor space than horizontal units.

No bake-out for wet motor: This Super-Seal motor, installed in a low-lying work room of a Connecticut paper mill, has repeatedly been under 5 to 6 feet of water. When the flood water recedes, the motor goes back into service without costly, time-consuming "bake-out." Poxeal and Silco-Flex insulations, used in Super-Seal motors, are impervious to moisture, dust, dirt, oils and most acids and alkalies.

So low, two fit where one used to go: SpaceMaker control center is the first completely new 2- to 5-kv motor controller in more than a decade. Its compact, two-high design cuts floor space in half. New flame-retardent, track-resistant Super Pyro-Shield insulation reduces controller size and weight, adds to reliability. Full drawout construction makes this the safest, most accessible controller available. The door cannot be opened unless the contactor is disconnected with all "live" connections isolated. One man can roll the contactor carriage out of the enclosure for obstruction-free inspection and maintenance. Contacts are completely accessible.

Which one of these productive ideas could be working for you?

A motor that shrugs off floods . . . a high-voltage motor control center . . . a vertical pump with simplified maintenance. These examples demonstrate the extra value that is standard with A-C . . . the greater efficiency and added productivity which are yours when you buy A-C products, systems and services. Call your Allis-Chalmers representative for details on A-C "worth-more" features. Or write Allis-Chalmers, Industrial Equipment Division, 903 S. 70th Street, Milwaukee 1, Wisconsin.

A-C INDUSTRIAL EQUIPMENT DIVISION: motors, generators, controls, rectifiers, pumps, compressors, crushers, mills, screens, kilns, coolers, industrial systems.

VALLEY IRON WORKS SUBSIDIARY: paper-making machinery.

OTHER A-C PRODUCTS: thermal, hydro and atomic electrical generating equipment; switchgear, transformers, unit substations; earth-moving equipment, engines, lift trucks.

A-1422

Super-Seal, Poxeal, SpaceMaker and *Pyro-Shield* are Allis-Chalmers trademarks.

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FINISH...

the prelude to PERFORMANCE

This dryer drum 12′ D x 75″ Face is CRODON-plated directly upon steel for hardness and durability.

The performance of your dryer drums deserves that extra fineness of best-surface-finish which vitally affects the quality of the paper you sell. There is more than simple help to be gained in your production from CRODON-plating—there is the more direct benefit of improved quality of your paper that helps your product in the market place.

For more than 30 years CRODON-plating has been applied to drum surfaces to provide operating efficiency and lowered long-range costs. These years of experience emphasize five of the benefits of the CRODON surface **finish** and its contribution to your machine **performance:**

Cleanliness	Assures freedom from rust and consequent staining.
Hardness	Gives economical long life through its durability and wear resistance.
Thermal Suitability	Provides uniform and high-performance conduction heat-transfer.
Adaptability	Enables select textured or mirror finishes tailored to product requirements.
Imprint	Fulfills a need for better finishes imparted to paper, a boost in quality for you to market.

Need this kind of help? Invite the CRODON man.

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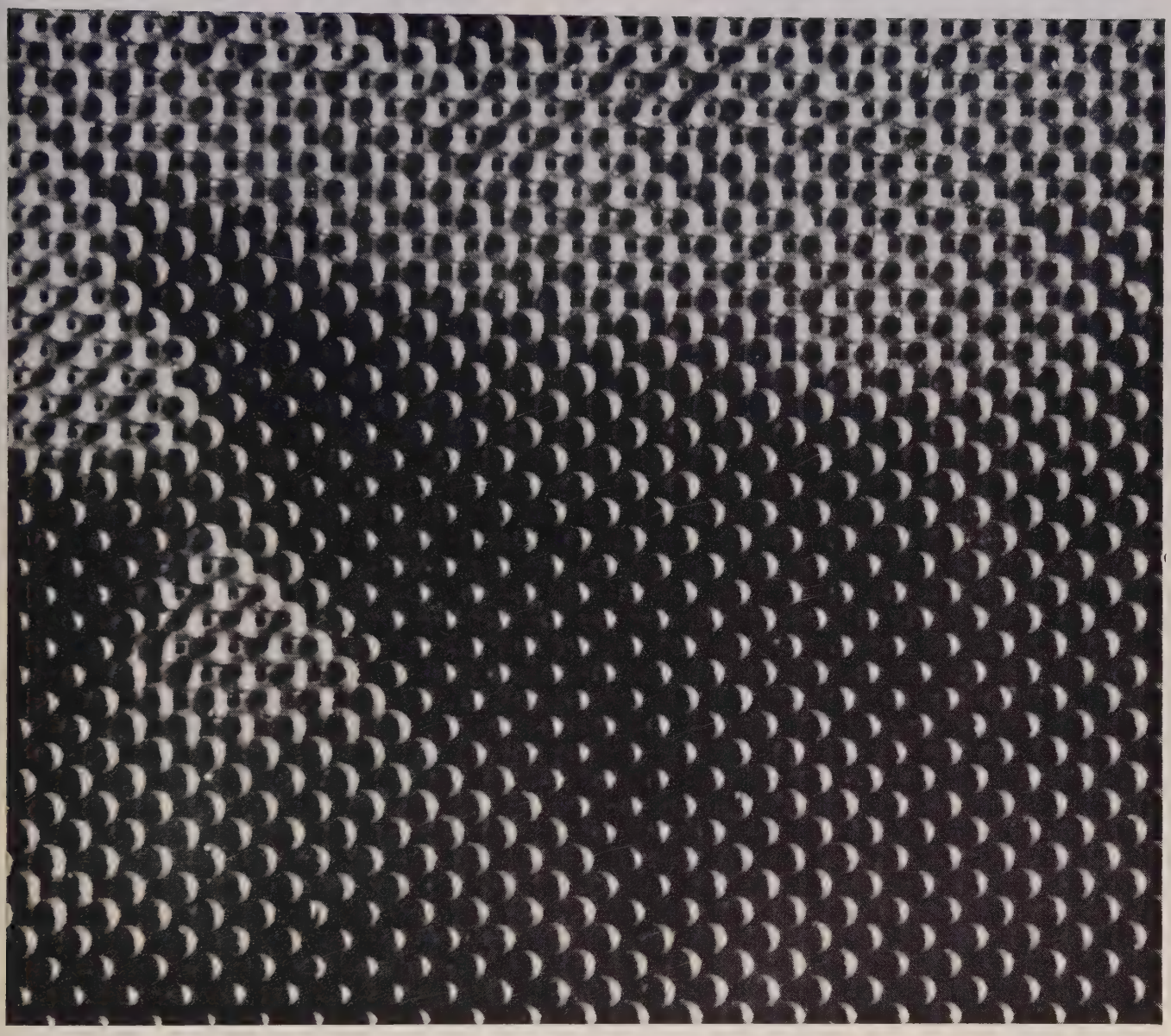

Superior pick resistance evident as 120-line copper engraving remains clean after 20,000 impressions.

NOW . . . with **NEW DOW LATEX 630**

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Here is the newest development in latex for paper coatings, new Dow Latex 630 . . . raising quality to a new high and giving you new manufacturing advantages and new selling features! New Dow Latex 630 gives you better control of paper uniformity . . . helps you stabilize paper surface quality . . . brings printing closer than ever to really true-to-life reproduction.

It will pay you to get detailed information now from The Dow Chemical Company, Midland, Michigan, Coatings Sales Department 1933FC3.

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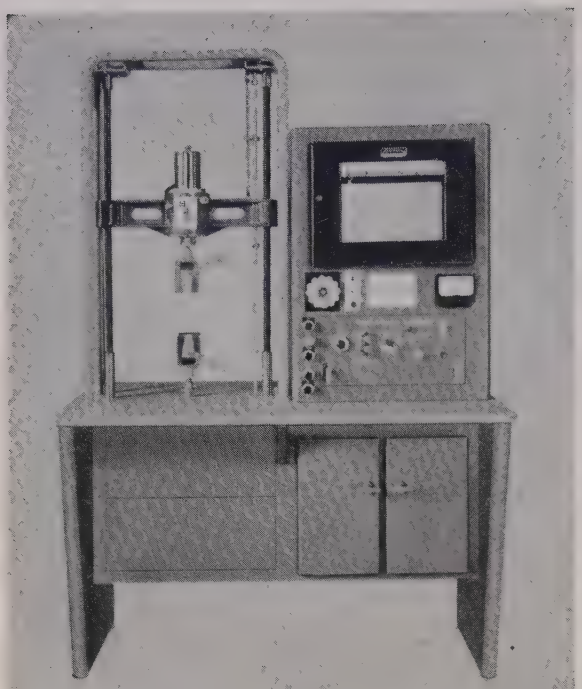
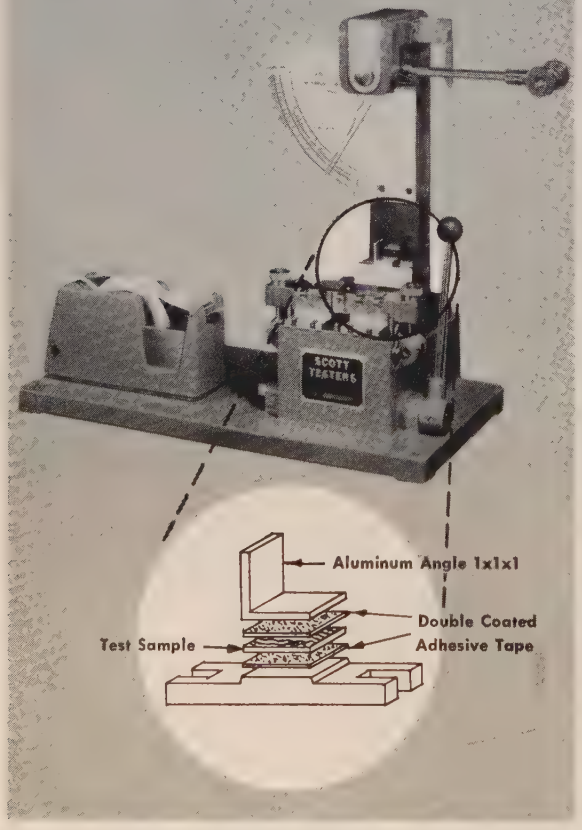


NEW PUSH-BUTTON SIMPLICITY FOR TENSILE TESTING!

Test tensile strength, edge tear, wet tensile, and other physical qualities of your paper products on the versatile Scott Model CRE Constant-Rate-of-Extension electronic tester. New push-button controls make paper testing a simple, fingertip operation . . . offer greater-than-ever operating convenience and testing economies. Ultra-precise *electronic weighing* system provides an infinite variety of crosshead speeds . . . wide selection of test load ranges . . . instant, automatic response to rapidly fluctuating loads.

For detailed test analyses, the ratio of crosshead speed to recorder chart speed can be adjusted to magnify stress-strain curves as high as 400:1. A new Scott clamp-locking assembly also reduces clamp-changing time to a *matter of seconds!* The Model CRE makes use of *all* Scott clamps and fixtures to meet ASTM, ISO, government and paper industry test methods. Most important, the Model CRE gives you this new testing precision, plus new testing simplicity . . . *at surprisingly low cost!*

SCOTT TESTERS FOR PAPER



TEST INTERNAL BOND STRENGTH

Measure the delamination adhesion, inter-fibre bond, ply separation strength of multi-construction papers with the fast, easy-to-work Scott Model B Tester. Its unique design enables the technician to prepare for accurate testing of *five* samples simultaneously . . . *means more tests per hour!* Each sample is split by the impact of a free-swinging pendulum. Direct readings of test values are indicated on a dial recorder. Tester comes complete with fixtures. Two test ranges: 0-.250 and .100-.500 in. lbs.

QUICK-CHANGING SCOTT CLAMPS AND FIXTURES

A-5 CLAMP FOR TENSILE TESTING

One of many Scott tensile clamps for testing paper — all instantly adaptable to the Model CRE Electronic Tester and other Scott tensile testers. The A-5 clamp features *two* gripping surfaces (1" or 2") in direction of test. Pressure on *upper* clamp reduces specimen thickness and minimizes slippage under test. Test capacities to 500 lbs.

FINCH WET TENSILE STIRRUP

Recognized throughout the paper industry, this fixture is adapted from the Finch Wet Tensile Design for use with Scott flat grip tensile jaws. For evaluating reduction in tensile strength of immersed paper specimen in compliance with ASTM Method of Test D-829 and TAPPI Method T-456M.

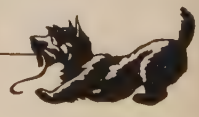
EDGE TEAR TEST STIRRUP

This fixture is another adaptation from the Finch design for fast set-up and positioning in Scott tensile clamps . . . for testing edge tear resistance of paper. Finished complete with interchangeable clamps of .025" and .050" radii. Meets ASTM Method of Test D-827 and TAPPI Method 470M.

WRITE FOR COMPLETE CATALOGS ON MODEL CRE . . . MODEL B . . . AND SCOTT CLAMPS

SCOTT TESTERS

THE SURE TEST . . . SCOTT!



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BOND YELLOW CP EXTRA
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Important news for paper-makers!

This unique new direct yellow . . . developed by National Aniline specifically for the paper trade . . . is the *first* to combine *all* of these operating advantages:

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In many cases, substantial economies can be effected in producing canary and bright green shades.

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Even in clay-filled sheets, there's usually no need to tint the wire side.

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For easy control of broke.

ABSOLUTELY CLEAN WHITE-WATERS!
Shows exceptional affinity for cellulosic fibers.

VERY GOOD COLD-WATER SOLUBILITY!
Add it dissolved or dry, winter or summer, with uniform results.

LESS VARIATION IN SHADE DURING RUNS!
Affected very little by pH changes on the machine.

FADES ON TONE!

TRIAL RUNS SUGGESTED

Ample stocks of National Bond Yellow CP Extra are immediately available. Your National Aniline representative will gladly schedule a trial in your mill. Phone, wire or write today!

This stock colored with National Bond Yellow CP Extra
For specifications see reverse side . . .

This sheet colored with

National®

BOND YELLOW

CP EXTRA

(patent applied for)

4 lbs. per ton of mixed, bleached pulp with 5% ash

Another example of what we are doing through research and through our expert knowledge of paper-dye application to help you make better colored papers more economically. Our technical staff and laboratories are always at your service.

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Rayonier offers the resources of 2 million acres of prime woodlands in the U. S. and Canada. To further protect your position and our future, last year we planted 21 million pine seedlings in the Southeast. With such big, scientifically farmed forests of hard and soft woods, you are assured the great paper-making pulps, sulfites and krafts — like Raybook, one of our quality bleached sulfites.

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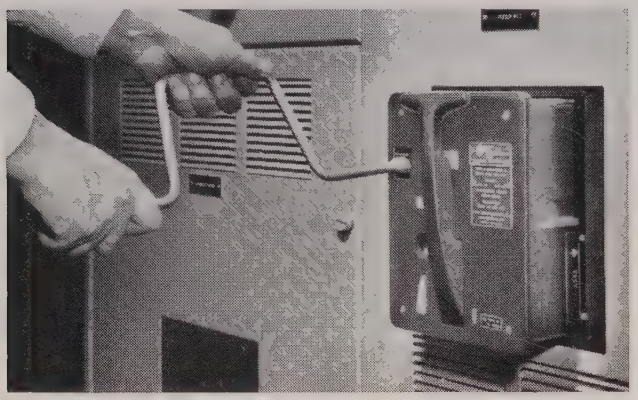
World's Most Complete Line of Paper-Making Pulps: *Western hemlock bleached sulfites; western softwood bleached sulfates; western red cedar bleached sulfates; southern pine bleached sulfates; southern hardwood bleached sulfates; southern pine bleached sulfites.*

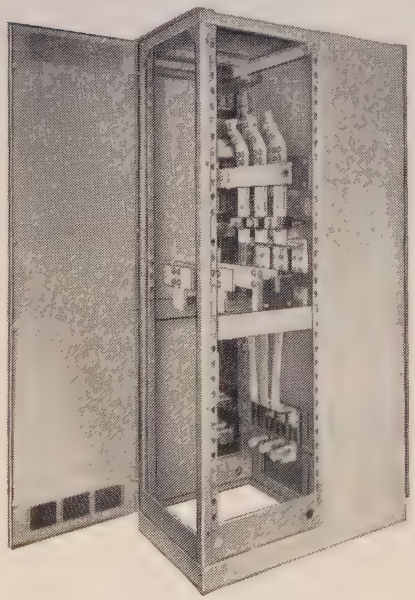
STILL THE MOST ADVANCED 600 VOLT SWITCHGEAR!

Four years ago, I-T-E introduced its completely new design advanced 600 volt switchgear with K-Line circuit breakers. In all this time right up to the present, no other gear modified or redesigned has been able to match it. Here still is today's most advanced gear, with easier operation, simpler upkeep, longer life, higher safety, and greater assurance of dependability than any other. Compare for yourself. For detailed literature, write I-T-E Circuit Breaker Co., Dept. SW, 1900 Hamilton St., Phila. 30, Pa.



Dependable drawout mechanism. Sturdy crank drive moves breaker on nonfriction rollers. Won't let you down when you need it most. Breaker can be padlocked in connected, test or disconnected positions. Door always remains completely closed for unequaled protection against dust contamination.

Complete isolation of breaker compartments. Each breaker is completely surrounded by solid steel barriers between it and other breaker compartments. No risk of arc gases contaminating an adjacent breaker through openings in partitions. Note also that secondary disconnects are located at the bottom of the compartment, safely removed from arc gases.



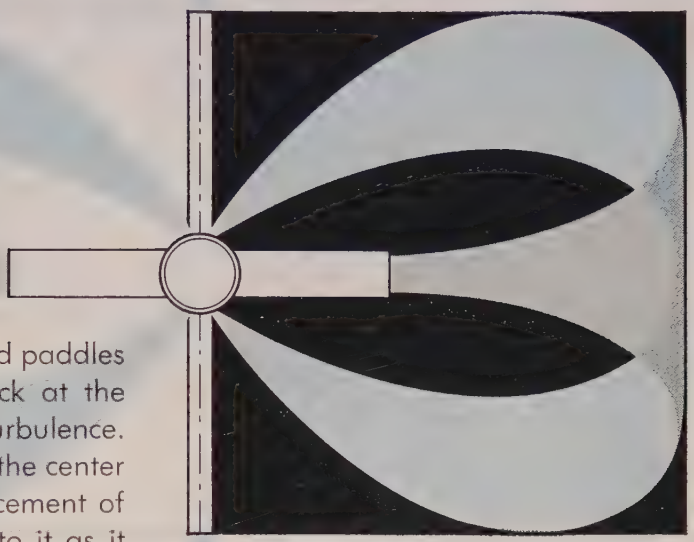
Silverplated bus. You pay no premium for this feature in I-T-E 600 volt switchgear. Aluminum bus is silverplated over its entire length for maximum conductivity. Reduces the required mass of the bus for a given maximum current. Bus is rigidly braced against movement in any direction from short circuits.

Easy-to-operate stored energy closing. Just pull down the handle, slow or fast as you please. Contacts close firmly in only 5 cycles for fast, uniform closure every time. Pulldown handle means easy operation of all breakers—top row, bottom row, or in the middle. Electrical closing mechanism, available optionally, uses a low current motor, not a solenoid.

I-T-E CIRCUIT BREAKER COMPANY

From S. W. Hooper: a pump principle for improved stock agitation

Cowan stock agitator provides a better blend with less than half the power



By substituting tubes for blades and paddles the Cowan agitator displaces stock at the tank edge without wasteful turbulence. Centrifugal force drives fluid from the center outward through the tube. Displacement of the fluid and the whirl imparted to it as it leaves the rotating tube combine to produce an agitation that continually moves the entire content back and forth between shaft and walls.

Both the flow through the tube and the power are subject to factors that can be readily calculated for accurate engineering of every separate installation.

It is this precision element in the design that permits measurable full blending with power consumption reduced by more than fifty per cent.

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We look forward to discussing with you the advantages of thorough blending, and will act promptly on your letter, phone call or wire.

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Resilient-seat stock valves

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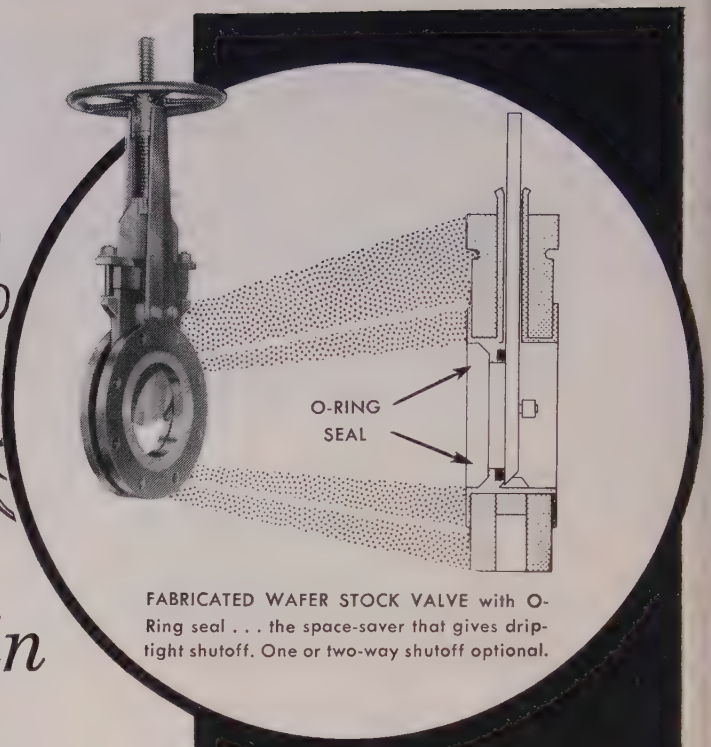
time and time again



FABRICATED WAFER STOCK VALVE with O-Ring seal . . . the space-saver that gives drip-tight shutoff. One or two-way shutoff optional.

Long-lasting Fabri-Valve resilient-seat stock valves have proved their worth by years of low maintenance operation in severe, tough shutoff service. Precision, time-tested engineering of the O-Ring seating in Fabri stock valves, assures you of positive, drip-tight shutoff under the most severe conditions. Choice of Viton "A" or Hycar O-Ring.

FABRI-CAST BONNETLESS STOCK VALVE with screwed-in resilient seat for positive shutoff and easy maintenance. Solid one-piece cast body with inverted packing gland.

FABRI RUBBER SEATING KNIFE-GATE VALVE. Compressible rubber seat rings assure drip-tight shutoff. When open, full port opening gives unobstructed flow.

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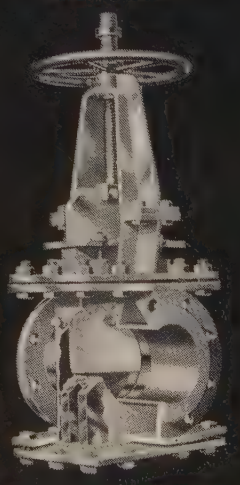
Fabri-cast Bonnetless Stock Valve



Fabri Rubber Seating Knife-Gate Valve

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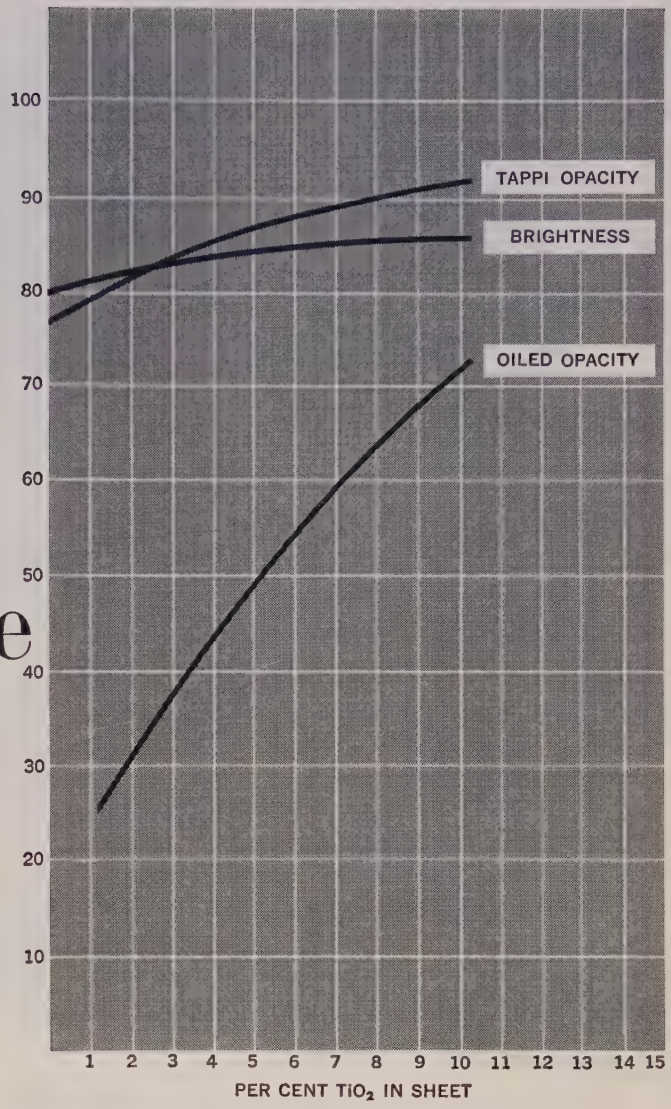
an outstanding titanium dioxide pigment made specifically for YOU



UNITANE® 0-120 This new pigment has been developed especially for the paper industry to give maximum retention. Designed specifically for wet-end additions, it has the same high brightness and opacity as the other well-known grades of UNITANE, and in tests with chlorinated starch has repeatedly given higher retention than any other titanium dioxide tested. These excellent properties are easily translated into savings for you—maximum opacity with minimum white water losses, high brightness with minimum show-through at lower basis weight, and good printed opacity. The curves illustrate the brightness, TAPPI opacity and oiled opacity obtained with UNITANE 0-120 at various concentrations of TiO_2 in the sheet.

A comprehensive report on the application of UNITANE 0-120 is available through your Cyanamid Pigments representative. Contact him today or write

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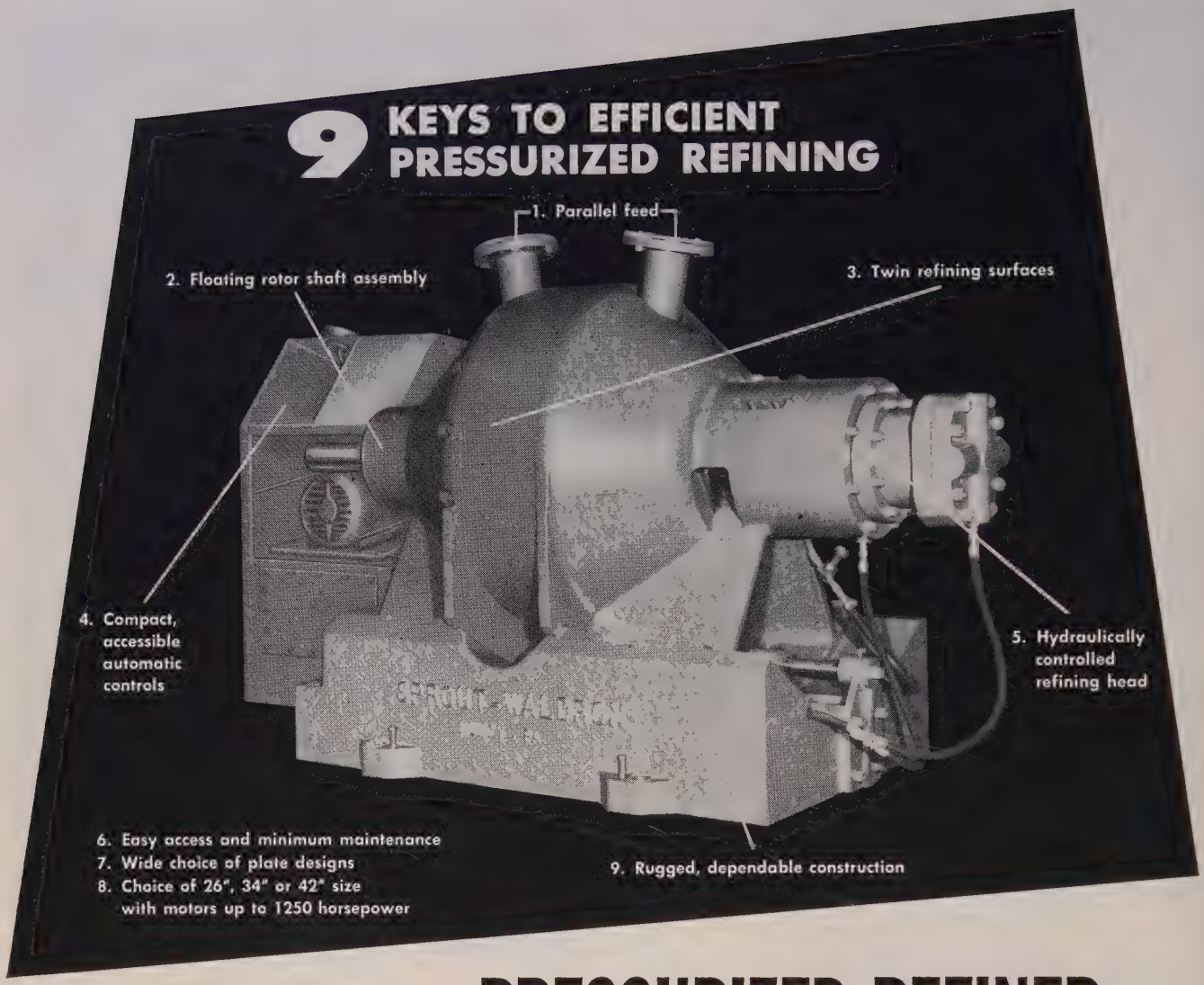
Lighter WHITER AND BRIGHTER WITH UNITANE


9 KEYS TO EFFICIENT PRESSURIZED REFINING
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2. Floating rotor shaft assembly
3. Twin refining surfaces
4. Compact, accessible automatic controls
5. Hydraulically controlled refining head
6. Easy access and minimum maintenance
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8. Choice of 26", 34" or 42" size with motors up to 1250 horsepower
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SPROUT-WALDRON PRESSURIZED REFINER

twice the normal capacity in a single unit

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Here is a different type stock preparation refiner designed for superior quality control, low operating costs and minimum maintenance. The parallel feed arrangement serves twin refining surfaces, giving twice the capacity of single disc units. Key to refining accuracy and dependability is the floating rotor shaft disc assembly which rotates between the fixed and hydraulically controlled movable heads. The flow of pulp is equally distributed between both sets of plates, assuring uniform refining and even plate wear. If you are looking for mechanical simplicity, high production and uniform quality, plus low operating and maintenance costs—get the facts on the Sprout-Waldron 20″, 26″, 34″ and 42″ pressurized refiners. Bulletins available on request.

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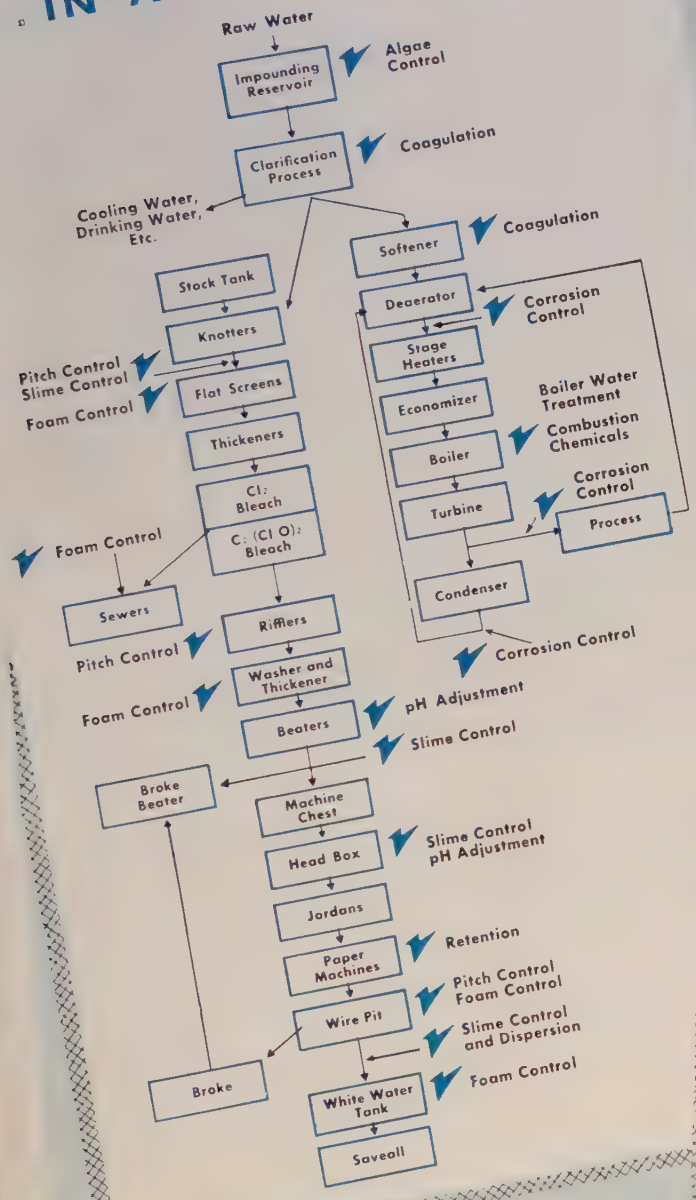
for Better Products at Lower Cost

. . . IN A TYPICAL MILL



NALCO has the *widest variety* of formulas to assure results in your mill, too. Here are some examples . . . representative Nalco products listed under headings which indicate the job they do. And the chart at left tells you where they are used. Your Nalco Representative will tell you more about them—or write direct to Nalco.

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Nalco Cuprose · Nalco 201 · Nalco 236
Nalco 21-S · Nalco 25-L · Nalco 237

COAGULATION
Nalco 600 · Nalco 650 · Nalco 680

COMBUSTION CHEMICALS
Nalco 155 · Nalco 156 · Nalco 156-C

FOAM CONTROL
Nalco 71 · Nalco 71-C · Nalco 71-K
Nalco 71-B · Nalco 71-D5 · Nalco 71-M

CORROSION CONTROL
Nalco 19 · Nalco 353
Nalco 35 · Nalco 918

pH ADJUSTMENT
Nalco 680 SP
Nalco No. 2 (liquid sodium aluminate)

PITCH CONTROL
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SLIME CONTROL AND DISPERSION
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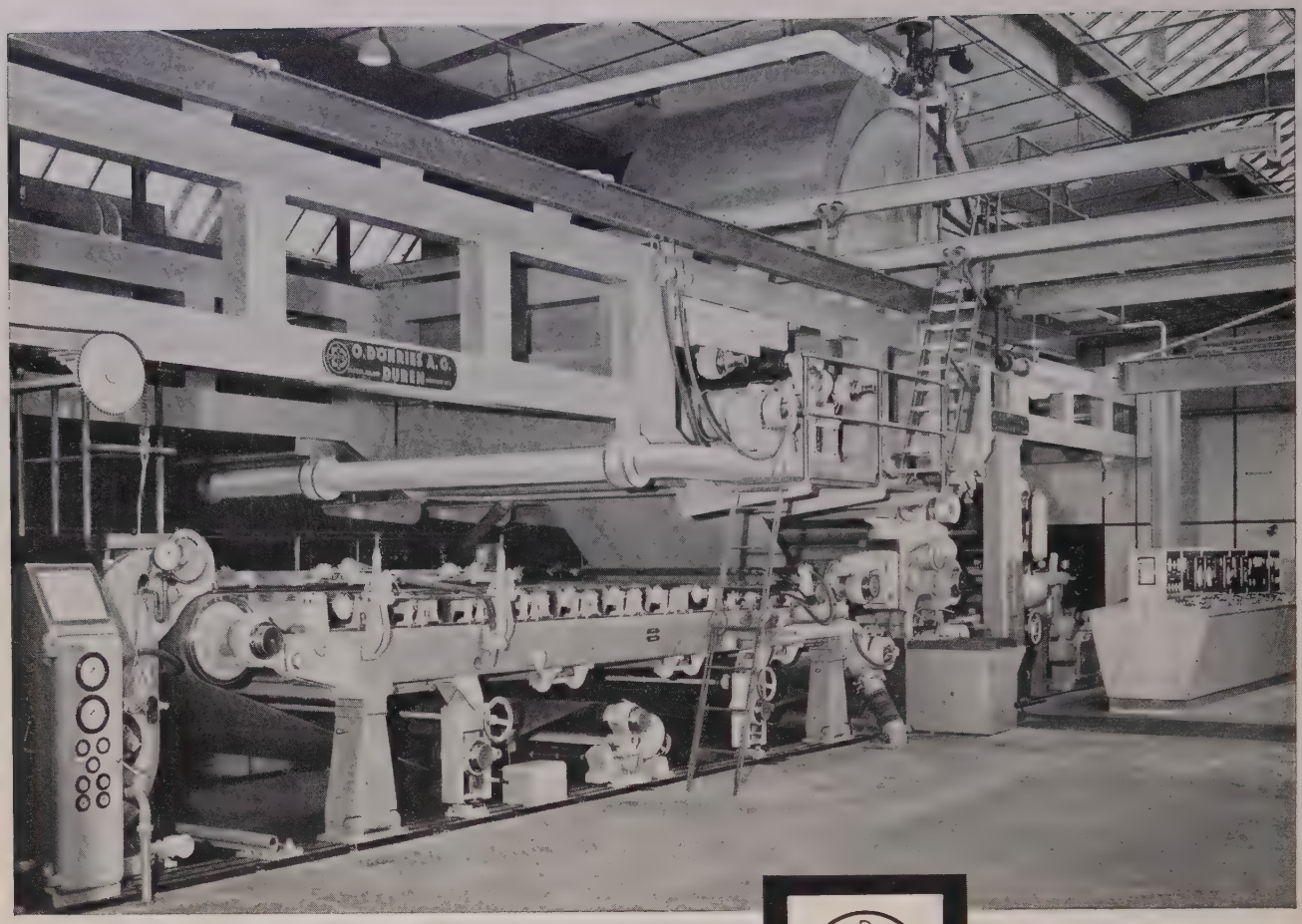

Precision

also in the field of paper machine engineering

This modern automatic pick-up machine is suitable for the production of pulp wadding, sanitary papers, tissue towels and thin M. G. papers

Special characteristics:

fully automatic operation of the whole machine from a control desk •

Special equipment for a quick change of wires, felts and doctors • Maximum running speed

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Agents: Bulkey, Dunton Pulp Company, Inc. 295, Madison Avenue, New York 17 N.Y./USA

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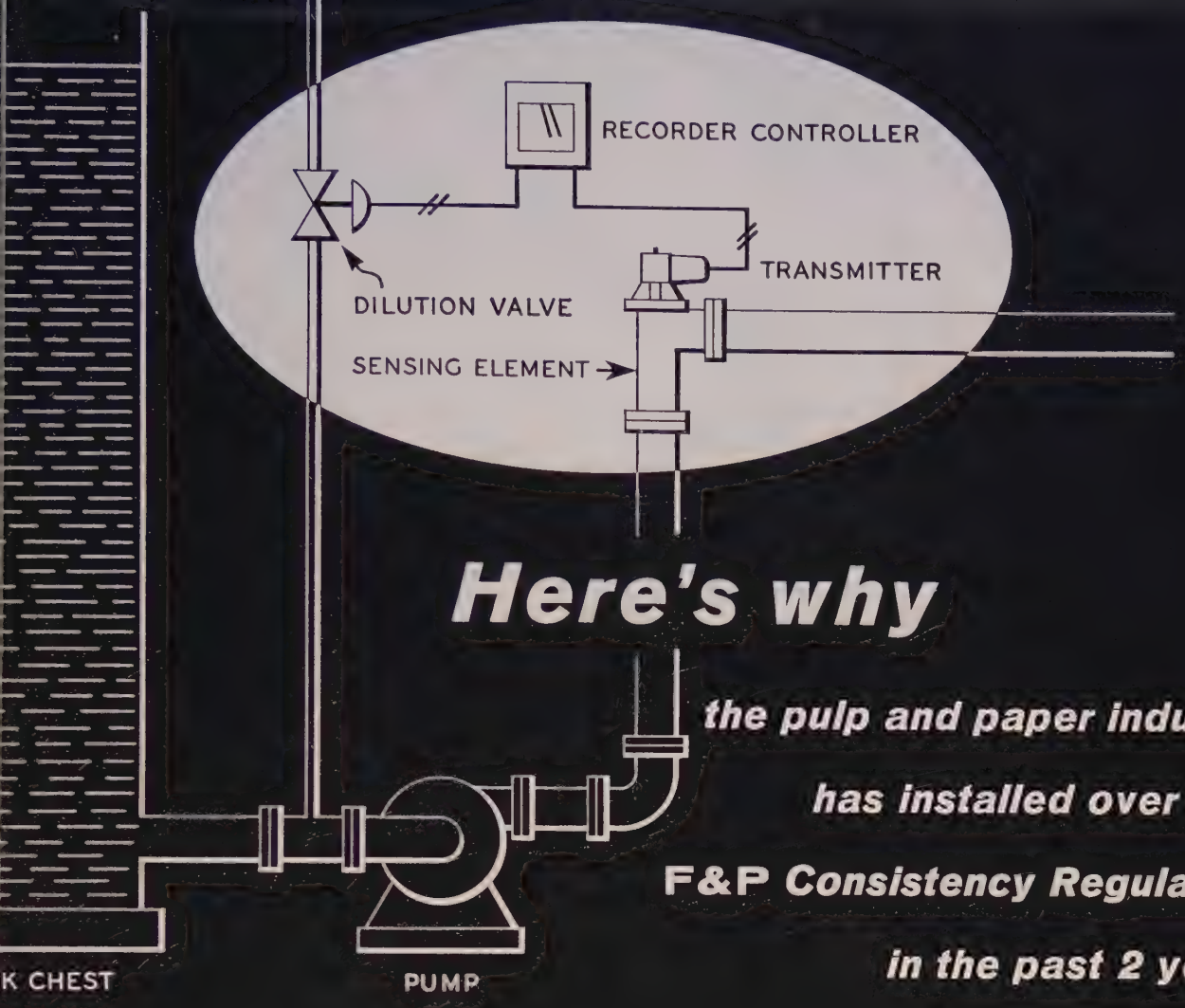


Here's why

the pulp and paper industry has installed over 600 F&P Consistency Regulators in the past 2 years

■ **Performance**—Has in-line sensing element . . . regulates to any consistency, from 2% to 8% without part changes . . . has high speed of response . . . accurate to better than 0.1% consistency . . . variable sensitivity . . . immune to changes in freeness and velocity. Another unit covers consistencies from 0.8% to 2.5%.

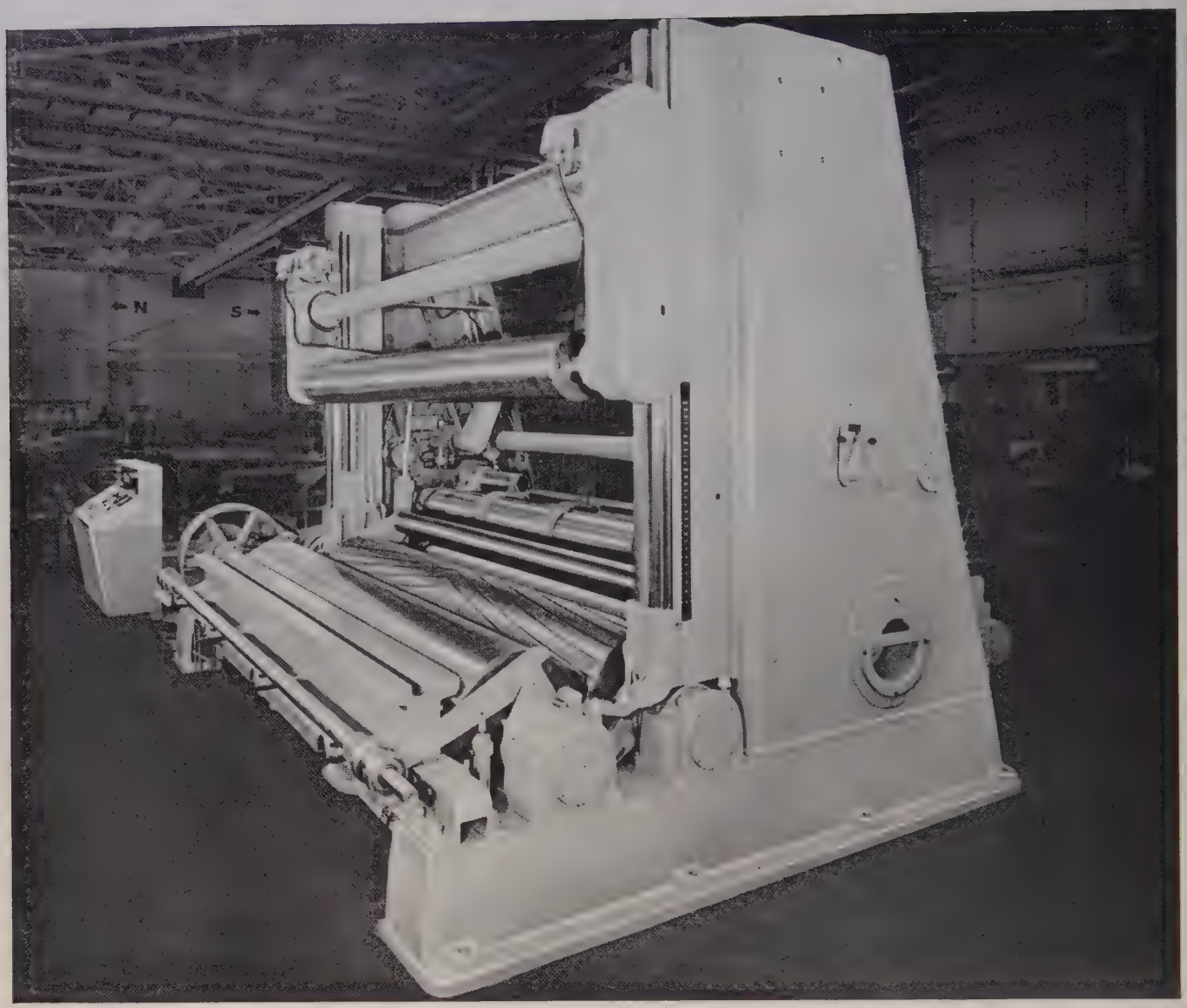
■ **Maintenance**—Minimum maintenance required . . . light weight (transmitter 40 lbs.) . . . easy to assemble . . . no seals or water purges . . . no electric drives . . . no critical bearings. Start-up assistance by factory trained specialists.

■ **Installation**—Low installation cost . . . no extra supports . . . minimum head room required above transmitter . . . small . . . light weight . . . easy to handle.

■ **Plus**—One manufacturer for all components (sensing element, transmitter, recorder, controller) . . . 4-week delivery on all sizes, from 6″ to 30″ pipe . . . economical price includes start-up assistance by qualified field service engineers.

Complete specifications on the Consistency Regulator are available from your local F&P field engineer, supported by pulp and paper industry managers and system engineers at Fischer & Porter Co., 1731 County Line Road, Warminster, Pa. In Canada, write Fischer & Porter (Canada) Ltd., 2700 Jane Street, Toronto.

FP FISCHER & PORTER COMPANY *COMPLETE PROCESS INSTRUMENTATION*



THE SPEEDMASTER

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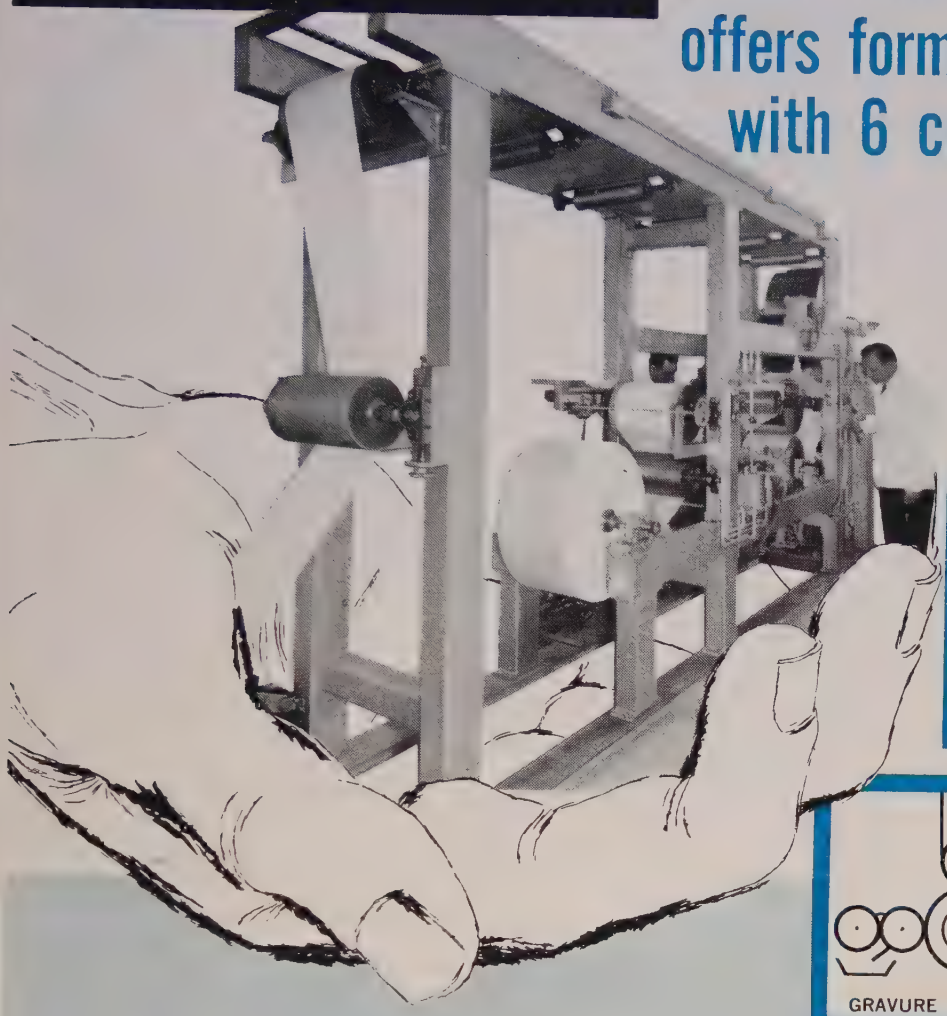

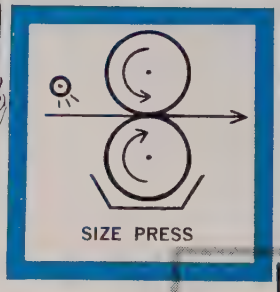

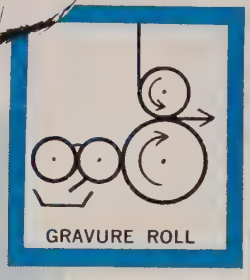

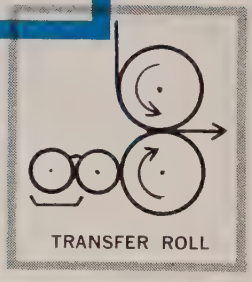

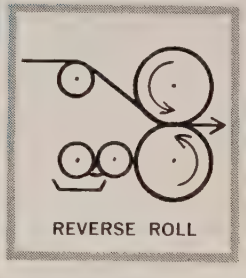

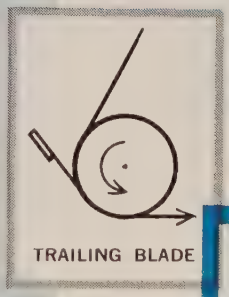

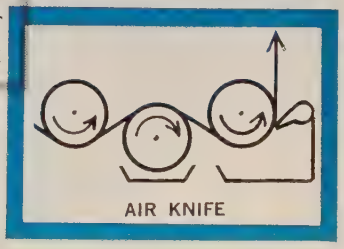

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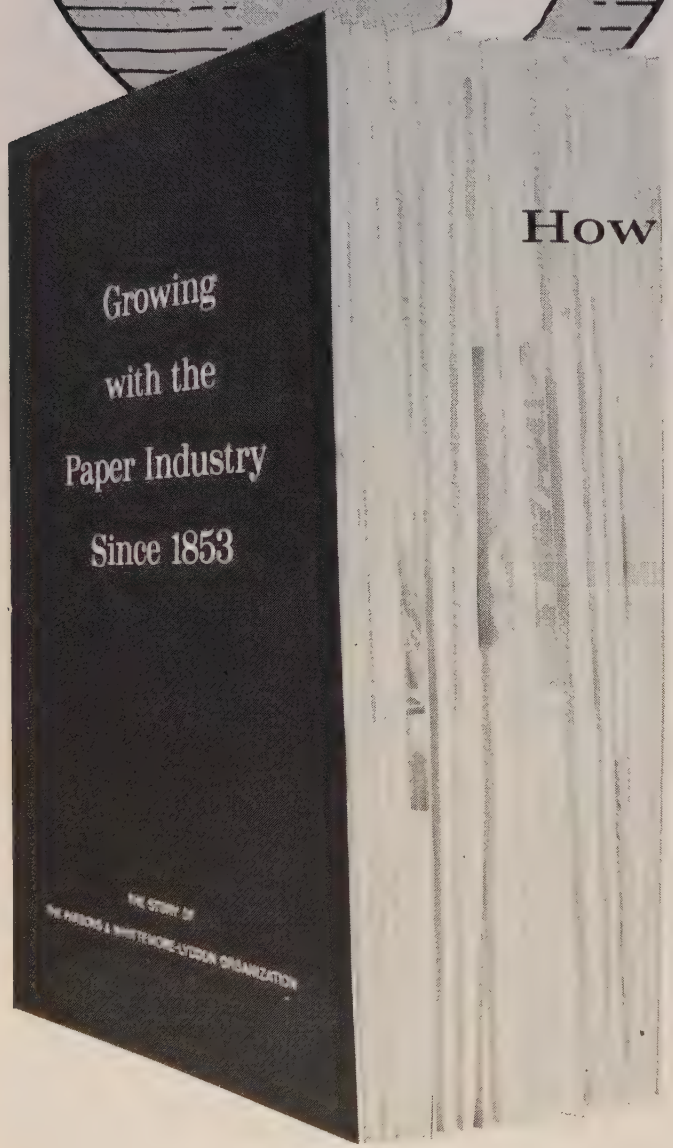

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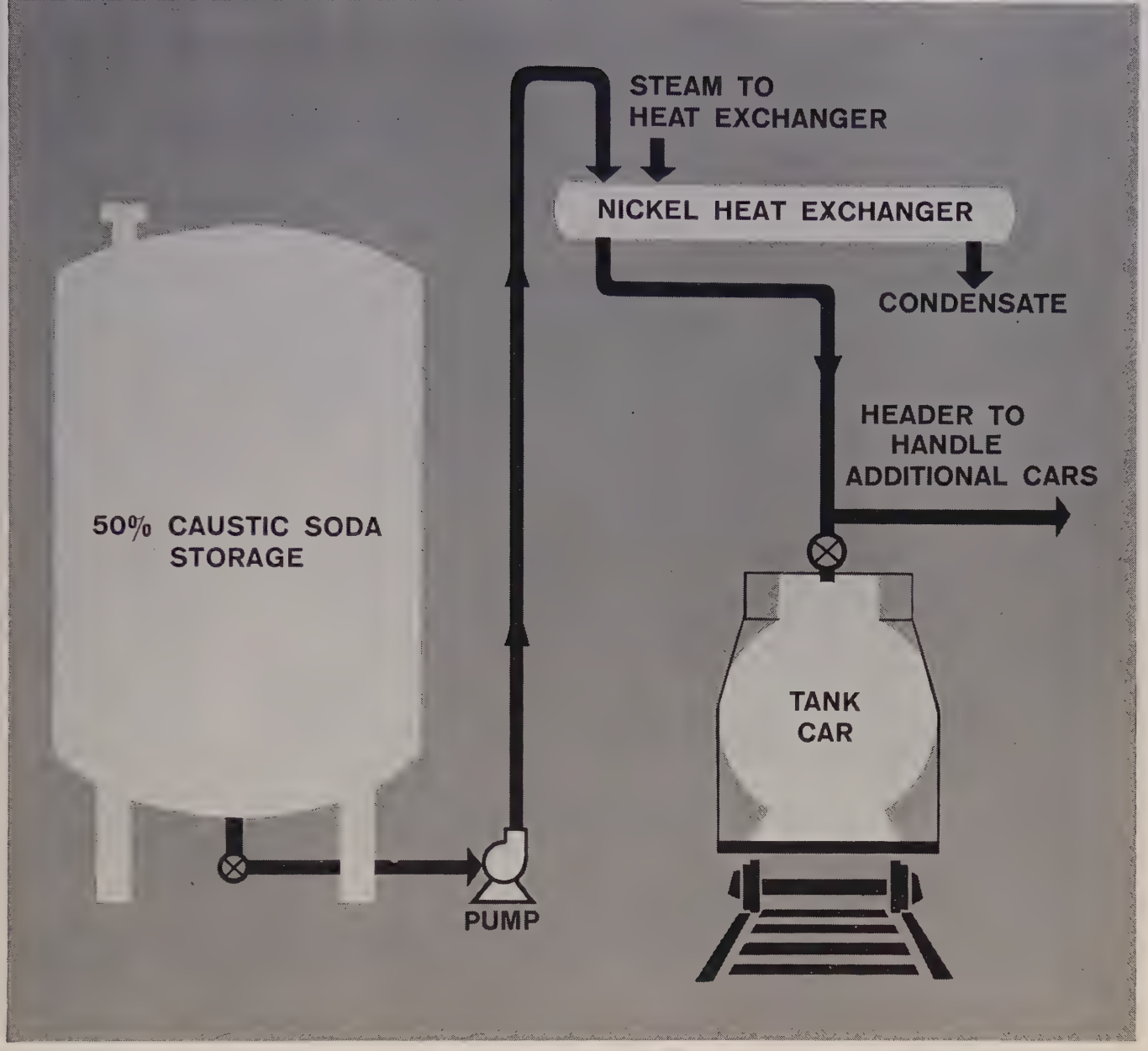

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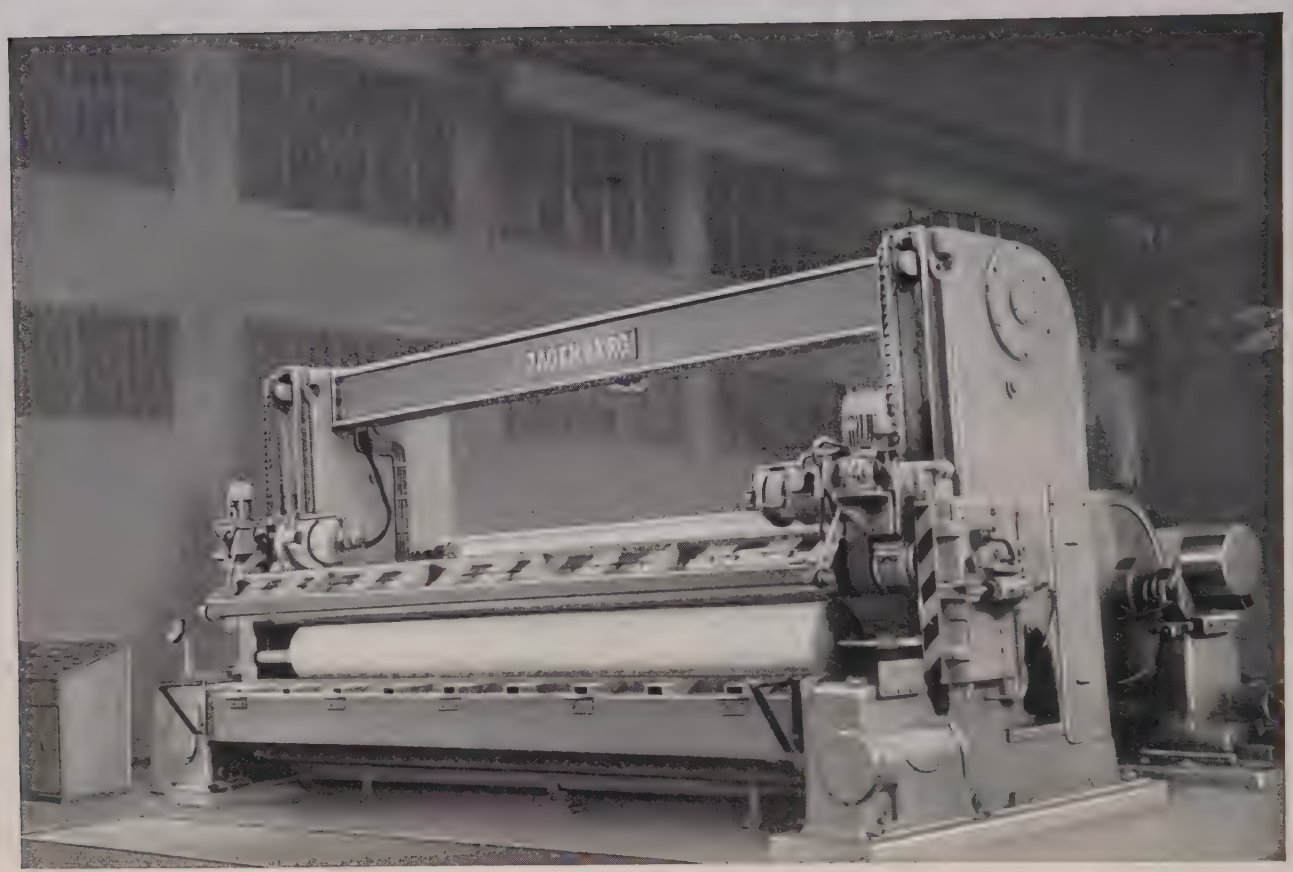

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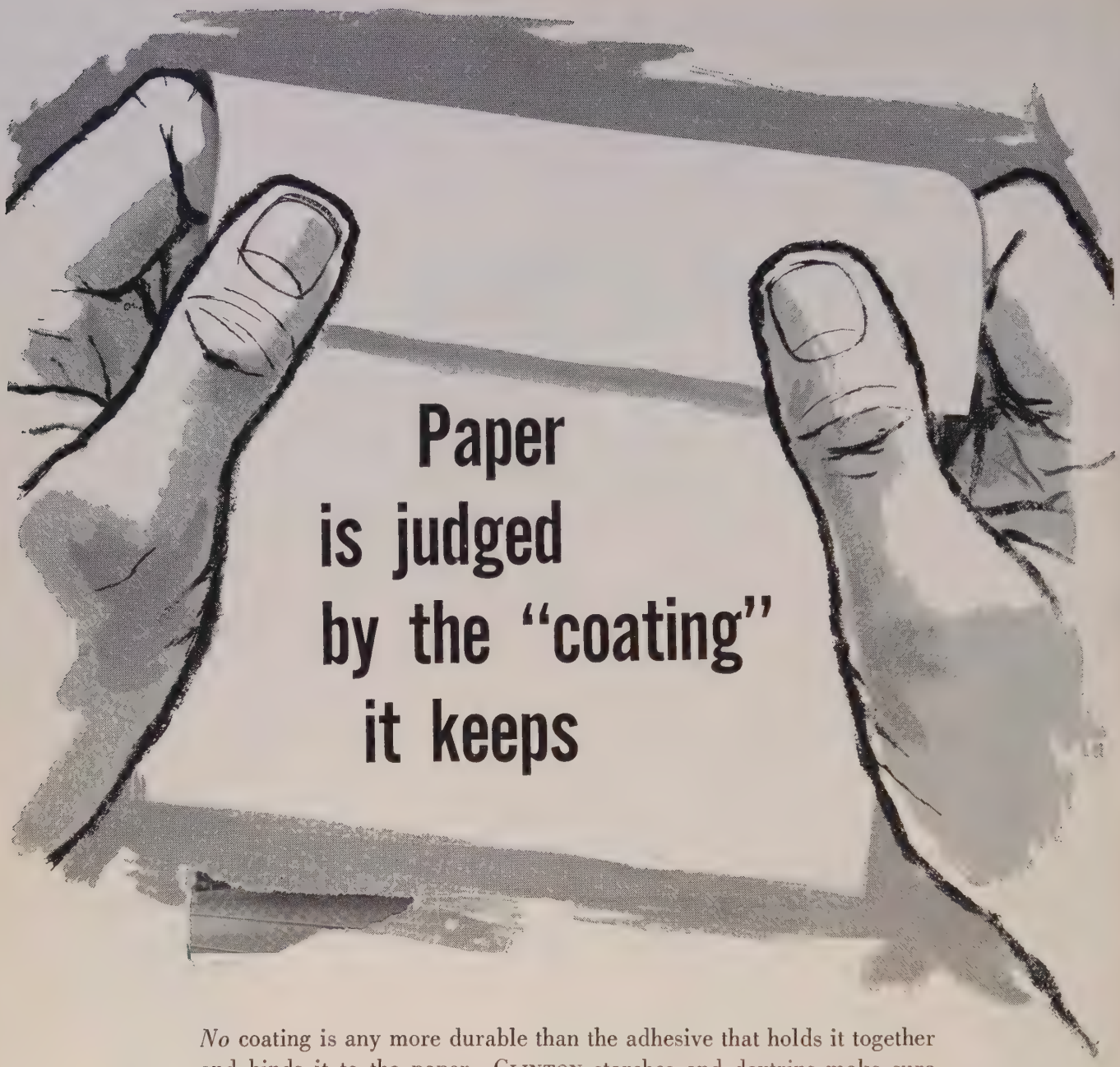

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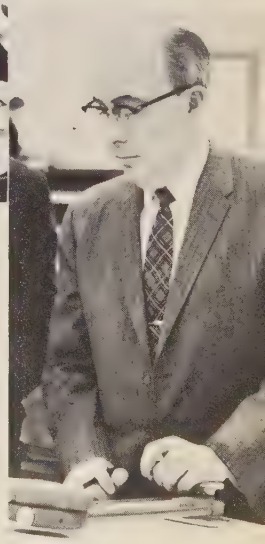

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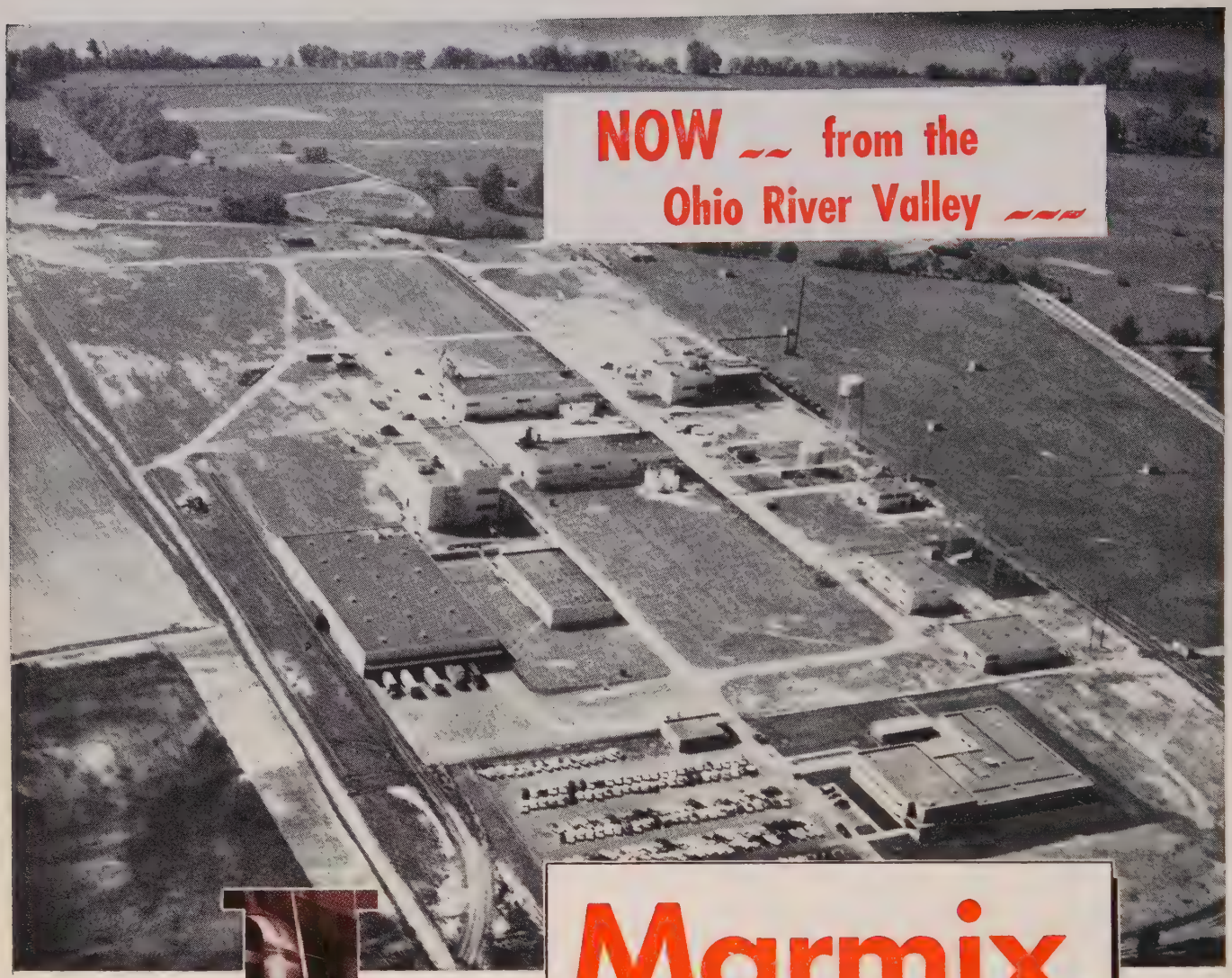

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Variation and Periodicity of Summerwood in Some Second-Growth Douglas-Fir

R. W. KENNEDY

Summerwood percentages and amounts were found to vary widely among trees and years. The variation among years was related significantly to precipitation, whereas the differences between individuals was attributed to heredity or microsite conditions. Highest summerwood percentages were found in those individual trees having the longest periods available for summerwood formation. The physiological mechanism of springwood–summerwood transition is discussed briefly.

THE most desirable Douglas-fir wood for the manufacture of pulp or structural timber is generally considered to be that of high specific gravity, since both yields of pulp per unit volume and strength of wood vary directly with this criterion of quality. Variation in specific gravity of this species can largely be accounted for by fluctuations in summerwood percentage. Smith (*10*) has found a high degree of correlation between specific gravity and summerwood percentage in second-growth Douglas-fir. This strong relationship remains unchanged regardless of the location of the growth rings with respect to the pith (*11*).

An assessment of the variation in percentage and time of summerwood formation, and an analysis of some environmental factors associated with its development are desirable first steps toward understanding the mechanism of latewood formation. Only one study appears to have been carried out concerning the environmental factors controlling the production of summerwood in Douglas-fir. Chalk (*3*) found that in England the formation of summerwood was related to the amount of moisture available during the period of its production. Springwood production, on the other hand, was favored by low average temperatures during May and June.

Larson (*6*) and Paul and Marts (*8*), working with the southern pines, have shown a correlation between the proportion of latewood and summer precipitation. However, neither of these studies may be applicable to Douglas-fir growing in Pacific Northwest coastal forests.

It was the purpose of this study to investigate the variation in percentage of summerwood in Douglas-fir. Differences between individual trees and years, and their interactions were analyzed. Variation in amount of earlywood and latewood formed from year to year was correlated with certain weather records.

MATERIALS AND METHOD

Dominant and codominant Douglas-fir growing on a variety of sites at the University of British Columbia Research Forest near Haney, B. C., were selected for study. A description of the climatic and soil conditions associated with the growth of these trees may be found in the work of Griffith (*4*), wherein their radial growth habit is described. Radial growth measurements were taken by Griffith at weekly intervals throughout the growing seasons from 1953 to 1957, employing a dial gage dendrometer (*13*) at breast height. The trees were felled in the fall of 1957, but cross-sectional disks cut at breast height were retained. From each disk, a small wood block was cut in such a way that the point measured by the dendrometer was included. Since the ages of the trees varied from 65 to 81 yr., the outermost five rings designated for study were all at an advanced age from the pith, eliminating juvenile wood as a source of variation.

Cross sections from each block were cut on a sliding microtome, stained with aniline safranin, and mounted in Canada balsam for microscopic study. The radial widths of the springwood and summerwood zones of each of the annual rings for the period 1954 to 1957 were determined. The values recorded for an individual ring were averages obtained through selecting three typical rows of tracheids. The distinction between springwood and summerwood was in accordance with Mork's definition (*9*), which describes summerwood as those tracheids having a radial lumen diameter less than twice the thickness of the common wall between two contiguous cells.

Although external measurements of growth were made with the dendrometer over a 5-yr. period from 1953 to 1957, the annual rings formed in 1953 were not considered in this study. This increment was found to be atypical due to the invariable presence of long tangential rows of traumatic resin canals within the earlywood portion of the ring. These probably formed in response to injury associated with the insertion of the screws needed for dendrometer contact points.

The dendrometer measurements were invariably greater than those determined microscopically, because the dendrometer recorded not only increase in xylem thickness, but cambial swelling and phloem production as well. Phloem formation alone may account for dendrometer readings 10% greater than actual xylem thickness, since Grillos and Smith (*5*) have found a ratio of 10 to 12 phloem elements for every 100 tracheids produced in Douglas-fir. Furthermore, the microscopic sections were observed to shrink about 4% radially due to the dehydration processes employed in preparing the slides.

From the data collected on sections studied under the microscope, the percentage of springwood for each ring was calculated. The approximate time that summerwood formation commenced was then determined as the date on which the weekly dendrometer

R. W. KENNEDY, Instructor, Faculty of Forestry, University of British Columbia, Vancouver, B. C., Canada.

readings indicated that a percentage of growth identical with the calculated springwood percentage had been completed. Implicit in this method is the assumption that phloem production proceeds at the same relative rate and over the same period of time as xylem formation. Bannan (*1*) has indicated, however, that while phloem production continues at a more or less uniform rate throughout the growing season, the rate of xylem formation reaches a maximum in late spring and then decreases. This results in a changing xylem to phloem ratio throughout the growing season, and contributes a small error to the determination of the date of initiation of summerwood formation. In spite of the lack of precision which exists in determining the exact date of summerwood formation, the method described provides some useful comparative information.

For each of seven different sites, three trees were investigated. In several instances it was necessary to examine more than three trees from a given site, since the microscopic measurements on the xylem of certain rings compared unfavorably with the dendrometer readings. Trees yielding external growth values in any year that were more than 30% higher than corresponding figures for xylem thickness were discarded. The reason for the unusually divergent values is not clear. The cambia of such trees may have been unusually active in producing phloem cells, or may have swollen excessively, particularly in the early spring.

Table I. Basic Data for 21 Dominant Douglas-Fir Trees

A, per cent summerwood and ring width. B, number of days during which springwood formed. C, total number of days in growing season

			A						B				C			
			Summerwood, %				Arith. av.,	Av. ring width 10^3 in.,	Period of springwood formation, days				Duration of growing season, days			
Site index	Tree no.	D.b.h., in.	1954	1955	1956	1957	1954–57	1954–57	1954	1955	1956	1957	1954	1955	1956	1957
180	340	23	40	36	37	36	37	84	74	77	54	66	165	163	159	131
	341	23	37	53	61	45	49	62	85	75	56	66	164	175	164	145
	344	20	33	46	22	33	33	50	93	65	55	76	154	174	163	127
170	231	26	17	33	42	44	34	69	107	94	57	57	139	160	165	121
	240	21	17	36	57	44	38	120	107	84	61	75	144	158	167	157
	238	16	57	60	50	50	54	56	60	66	56	52	152	163	167	142
160	105	32	59	48	63	61	58	150	35	88	56	50	142	164	165	152
	128	20	6	19	44	33	25	63	125	115	65	57	156	161	163	116
	92	17	28	43	62	42	44	102	101	83	55	62	153	179	163	143
150	87	22	25	30	47	38	35	83	103	83	46	63	153	148	154	127
	58	20	68	70	69	66	68	154	45	64	48	54	151	163	163	176
	67	16	41	36	33	29	35	56	79	83	69	60	163	165	167	139
140	8	19	4	29	40	27	25	82	139	90	70	50	159	159	164	96
	24	18	7	33	42	25	27	53	128	79	63	58	163	145	163	113
	23	17	38	33	46	28	36	50	74	76	46	63	161	152	153	127
115	163	13	37	48	53	47	46	93	74	61	46	58	141	169	156	129
	172	12	45	44	33	37	40	58	60	51	52	57	157	164	167	130
	211	11	37	36	43	33	37	81	79	85	56	63	159	153	168	158
85	278	10	71	65	53	70	65	84	41	61	41	62	156	171	168	146
	290	10	35	33	45	29	35	56	95	86	52	66	154	170	168	122
	270	9	32	31	38	31	33	74	81	86	64	68	160	147	168	111
Arithmetic av.			35	41	46	40	..	80	85	79	56	61	155	162	163	134
Weighted av.			37	43	51	44										

RESULTS AND DISCUSSION

Variation in Summerwood Percentage Among Trees

The basic data for summerwood percentage of 4 consecutive years are recorded in Table I, A. Analysis of variance revealed that both site and year had a significant influence on summerwood percentage. However, there was no correlation between site index and per cent summerwood. "Site" was therefore discarded in favor of "individual tree" as a source of variation. The individual tree term was significant in the reworked analysis of variance, thus indicating that individuals have different capacities for formation of summerwood. The differences among individuals may be due to varying microsite and/or genetic influences. If a microsite control of summerwood exists, it is not likely to be related to growth rate, since neither site index nor the ranking of large, medium and small trees within site were significant.

Table I, A also lists the summerwood percentage of each tree averaged over all years. Individual mean values ranged from 25 to 68%. In general, those trees with the highest percentages of summerwood are consistently above the average for any given year (examples: tree nos. 238, 105, 58, 278). Similarly, those trees with the lowest summerwood percentages are consistently below average for their years (examples: tree nos. 128, 8, 24).

Variation in Average Summerwood Percentage Among Years

Both weighted and nonweighted average summerwood percentages were determined for each of the four years. Weighted means were determined by dividing the total amount of summerwood formed in all rings by the sum of the ring widths for the given year. Nonweighted means were calculated simply as the arithmetic average of the 21 trees in a particular year. Arithmetic averages ranged from 35 to 46%, while weighted means varied from 37 to 51%.

An attempt was made to relate annual variation in summerwood percentage with available weather records. Total precipitation, minimum, maximum and average temperature, and total hours of sunshine for each of the months March through July were correlated with weighted average summerwood percentages for the four years studied. Possibly due to the limited number of degrees of freedom, only one correlation coefficient proved significant. However, all those over

Table II. Weather Data and Correlation Coefficients with Summerwood Percentage

Year	Av. summerwood percentage (weighted)	Precipitation, in. March	Precipitation, in. April	Av. temp., °F. April	Av. temp., °F. July	Max. temp., °F. April	Max. temp., °F. July	Sunshine, hr., April
1954	37	4	8	44	59	65	78	80
1955	43	11	7	43	60	67	82	130
1956	51	11	2	50	64	78	93	160
1957	44	9	4	48	60	77	79	120
Mean		8.75	5.25	46	61	72	83	122
r		0.82	−0.92	0.80	0.94	0.83	0.89	0.97[a]

[a] Significant at 5% level of probability.

0.80 may be considered to indicate trends which might have been significant had more years been studied. These more important correlation coefficients are summarized in Table II. Similar results could be expected using the summerwood percentages determined arithmetically, since the correlation coefficient between the two expressions of per cent summerwood was 0.99.

Weather in the month of April appeared to have the strongest influence on summerwood percentage. The data indicate that low precipitation, high temperatures, and long periods of sunshine promote high summerwood percentages. March precipitation, on the other hand, may be positively correlated with summerwood percentages. July temperatures also indicate possible positive correlation with per cent summerwood.

The fact that 1954 represents the year in which the lowest *percentage* of summerwood was formed should not be interpreted to mean that it was a particularly unfavorable year for the production of a large *amount* of summerwood. In fact, as indicated by Fig. 1, the average radial width of summerwood formed was the same in both 1954 and 1956, the extreme years in percentage summerwood production. The absolute amount of springwood varied greatly between these two years; in 1954 almost twice as much was formed as in 1956. Thus, it may be concluded that environmental conditions in 1954 led to a low summerwood percentage because of the favorable conditions for springwood formation.

The high precipitation recorded in April and May of 1954 and 1955, coupled with low spring temperatures, appears to have led to conditions particularly well-suited to formation of increased amounts of springwood. Correlation coefficients obtained by relating weather data for April and May to average amounts of springwood are presented in Table III. Only rainfall shows reasonable correlation with quantity of earlywood. Thus, it may be assumed that a high amount of spring rainfall is the chief annual weather factor in production of large amounts of springwood.

Although springwood production fell to a 4-year low in 1957, percentage of summerwood for that year was only average, due to the fact that there was a corresponding decrease in amount of summerwood formed in 1957 as compared to the three previous years. This decrease in amount of summerwood was correlated significantly with the unusually low May and June rainfall, which totaled only 5 in. (Table IV). In contrast, the combined May and June rainfall was essentially the same in the 1954 to 1956 seasons (12, 11 and 12 in., respectively).

Table III. Weather Data and Correlation Coefficients with Amount of Springwood

Year	Radial width of springwood, 10^3 in.	Precipitation, in. April	Precipitation, in. May	Precipitation, in. April and May	Temperature, °F. April	Temperature, °F. May	Temperature, °F. April and May
1954	65	8	6	14	44	54	98
1955	51	7	6	13	43	48	91
1956	37	2	2	4	50	57	107
1957	30	4	1	5	48	57	105
r		0.86	0.93	0.92	−0.78	−0.53	−0.67

There was no significant correlation between precipitation and quantity of latewood considering the months of May and June separately. Although rainfall in May, 1956, was low, the June precipitation was unusually high, thus bringing the total for the two months up to the May and June figure of the previous two years. Thus, in spite of the low May rainfall in 1956, the heavy June precipitation may have had the effect of stimulating summerwood production, since it generally began to form during this month in 1956. This observation bears some similarity with the work of Chalk (*3*), who found that amount of rainfall received by Douglas-fir trees during the time of summerwood formation critically influenced the volume of summerwood formed.

As a corollary to the low rainfall in May and June of 1957, the sum of the average temperatures for these two months reached a 4-year peak. Temperature therefore was negatively correlated with summerwood

Table IV. Weather Data and Correlation Coefficients with Amount of Summerwood

Year	Radial width of summerwood, 10^3 in.	Precipitation, in. May	Precipitation, in. June	Precipitation, in. May and June	Temperature, °F. May	Temperature, °F. June	Temperature, °F. May and June
1954	38	6	6	12	54	55	109
1955	39	6	5	11	48	56	104
1956	38	2	10	12	57	55	112
1957	23	1	4	5	57	59	116
r		0.76	0.54	0.97[a]	−0.52	−0.95[a]	−0.80

[a] Significant at 5% level of probability.

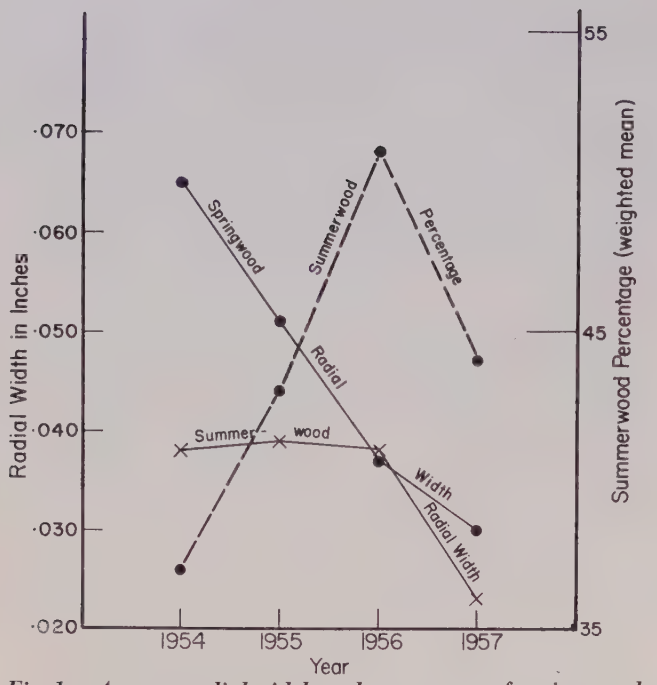

Fig. 1. Average radial width and percentage of springwood and summerwood formed in the years 1954 to 1957

production, although not significantly ($r = -0.80$). Average June temperature showed a significant negative correlation with summerwood amount, but may have little practical significance, since it varied only 4° during the 4-yr. period.

Although summerwood production generally proceeded at least through the months of July and August, no significant correlation between summerwood production and weather was found for these months.

Periodicity of Summerwood Initiation

Regardless of year, radial growth resumed during a 2-week period in late April, and showed no consistent pattern with individual trees. The approximate average calendar date of initiation of summerwood formation can be obtained by adding the period of springwood formation in days (Table I, B) to April 20. Thus in 1954 and 1955, summerwood formation commenced in the average tree about July 11, whereas in 1956 and 1957, it began on June 17. Considerable variations around these averages are evident from Table 1, B. For example, summerwood formation began as early as late May or as late as early September.

Variation in Summerwood Percentages of Individual Trees Within and Among Years

The data of Table I, A were submitted to simple linear correlation analyses with various periodic and growth factors. The results are presented in Table V.

Within a given year, summerwood percentage was highly correlated with the period of summerwood formation (column 4), with one exception. Thus, the longer the duration of summerwood formation, the higher its percentage. Referring to columns 3 and 5 of Table V, and considering the entire 4-year period, it can be seen that higher percentages of summerwood were correlated positively with period of summerwood formation, negatively with period of springwood formation, and not significantly with duration of growing season. Thus, a longer length of time for summerwood production is related to an early cessation of springwood formation, rather than to a longer growing season. For example, consider the trees in 1954 forming the extremes in summerwood percentage (Table I). Tree 278, with a growing season of 156 days, formed springwood for a very short period (41 days), thus 71% of its growth was summerwood. Tree 8, with almost the same length of growing season, formed springwood for 139 days, and therefore produced only 4% summerwood.

Examining these correlation coefficients for individual years, it may be seen that in 1957, summerwood percentage was again correlated with period of summerwood formation. However, the percentage of summerwood for this year was not correlated with period of springwood formation, but instead with length of growing season. Inspection of Table I, C shows the 1957 growing season to be shorter than that of the previous three years, and highly variable from tree to tree, with the result that trees exhibiting short growing seasons had low summerwood percentages regardless of the duration of springwood formation. For example, tree 8 had only a 50-day period of springwood formation (11 days less than the average for the year), yet summerwood percentage was a low 27% due to the short, 96-day growing season. In comparison, tree 278 had a 62-day period of springwood formation, but a much longer growing season of 146 days, resulting in an increment that was 70% summerwood.

Within individual trees, per cent summerwood was correlated positively with width of summerwood, regardless of year. Approximately 56% of the variation in summerwood percentage was accounted for by width of summerwood. The width of springwood, however, had an annually variable effect on per cent summerwood. Considering all years together, the width of the springwood band had only a small, but nonetheless significant, influence on summerwood percentage, accounting for 14% of its variation. In 1956 however, width of springwood was positively correlated with summerwood percentage, and thus is opposed to the general trend over all years. Evidently, in 1956 those trees with highest amounts of springwood must have had unusually high amounts of summerwood, in order that the amount of each could be positively correlated with summerwood percentage. This leads to the highly significant correlation coeffi-

Table V. Simple Correlation Coefficients Between Periodic or Growth Factors and Summerwood Percentage

(1) Year	(2) Period from April 1 to start of growth, days	(3) Period of springwood formation, days	(4) Period of summerwood formation, days	(5) Duration of growing season, days	(6) Width of springwood, in.	(7) Width of summerwood, in.	(8) Total ring width, in.
1954	N. S.[a]	−0.97[c]	0.95	N. S.	−0.76[c]	0.81[c]	N. S.
1955	N. S.	−0.73[c]	0.77[c]	N. S.	N. S.	0.78[c]	0.48[b]
1956	N. S.	N. S.	N. S.	N. S.	0.57[c]	0.89[c]	0.85[c]
1957	N. S.	N. S.	0.74[c]	0.67[c]	N. S.	0.74[c]	0.49[b]
1954–57	N. S.	−0.70[c]	0.76[c]	N. S.	−0.37[c]	0.75[c]	0.27[b]

[a] Not significant. [b] Significant at 5% level of probability. [c] Significant at 1% level of probability.

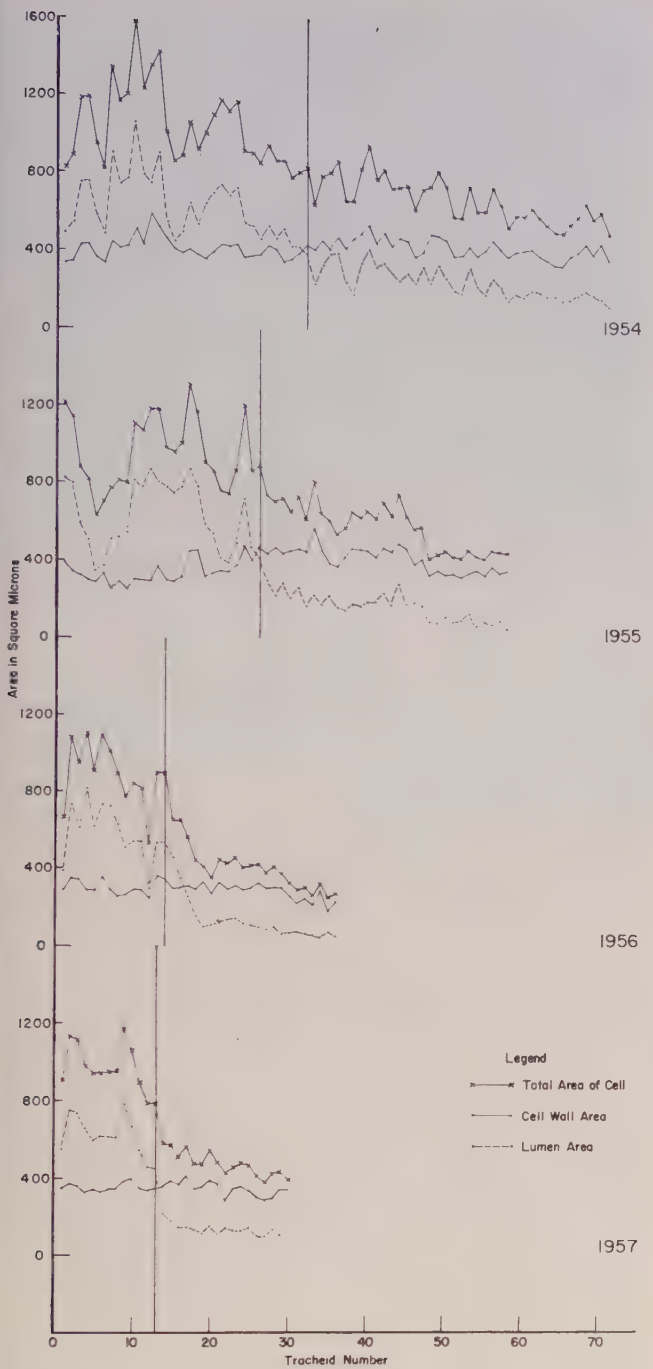

Fig. 2. Patterns of cross-sectional area of a typical row of tracheids (tree no. 172). Vertical lines represent division between springwood and summerwood using Mork's definition

cient between total ring width and per cent summerwood for this year.

The generally positive correlation of both width of summerwood and total ring width on summerwood percentage and the negative effect of springwood width can be interpreted to indicate that the wider annual rings have greater percentages of summerwood due to increased amounts of summerwood and correspondingly less springwood. These observations do not support the statement often made that faster rates of growth produce wood of lower density due to a lack of summerwood.

Mechanism of Summerwood Initiation

The stimulus controlling initiation of summerwood remains uncertain. Although cell wall thickness is obviously greater in cells of summerwood, the amount of cell-wall substance laid down seemingly does not differ from that of springwood tracheids. While the amount of cell-wall substance remains constant, the radial diameter of the cell lumens changes rather abruptly from the springwood to summerwood zone. This is shown graphically in Fig. 2, which represents the 1954 to 1957 annual rings of tree no. 172. Figure 2 was constructed by tracing onto paper a highly magnified image of the cross section of a typical radial row of tracheids in each ring. The tracings of the individual cell walls and lumens were cut from the paper and weighed on an analytical balance. Areas were determined by applying a conversion factor obtained by weighing pieces of paper of known area.

The physiological mechanism regulating the amount of postcambial radial enlargement of the differentiating tracheids may therefore be the critical one in determining the time at which summerwood tracheids will first be formed. Wareing (*12*) and Larson (*7*) have concluded that radial cell diameter is dependent upon the level of auxin reaching the cambium. Since auxin is synthesized in largest quantity during the period of bud swelling and active apical growth, and is depressed as terminal growth subsides, the formation of springwood may be associated with terminal elongation. A comparatively abrupt cessation in terminal growth would lead to a sudden drop in auxin availability, and hence to an abrupt springwood-summerwood transition such as is indicated in Fig. 2. Buckland (*2*) has compared the terminal shoot growth of four western conifers over a single growing season, using 8 to 10 yr. old trees. Douglas-fir completed both lateral and leader shoot growth before and more abruptly than the other three species (grand fir, western hemlock, western red cedar). These latter species, in contrast, generally have a smaller amount of summerwood than Douglas-fir, and display a pattern of gradual springwood-summerwood transition.

SUMMARY

The following conclusions can be drawn as a result of this investigation:

1. Summerwood percentage varies widely between trees and between years. Variations between trees within a year is greater than that between years within an individual tree. The difference between trees may be due to heredity or microsite conditions.

2. Mean annual summerwood percentage was highest in 1956, when springwood production was depressed, and the amount of summerwood formed was normal. Reduced quantities of springwood are associated with low April and May precipitation, whereas small amounts of summerwood are formed when May and June rainfall is low.

3. In general, highest percentages of summerwood were found in those individual trees which had the longest periods available for summerwood formation. Long periods of summerwood formation were associated with those individuals that ceased springwood formation early in 1954 and 1955, whereas in 1957 differences in length of growing season critically influenced the period of summerwood formation.

4. Within individual trees, the single factor exhibiting the greatest degree of correlation with summerwood percentage was the width of the summerwood

band. This was the only factor consistently significant (positively) in all years.

5. Summerwood tracheids in Douglas-fir appear to differ from those of the springwood primarily in radial diameter rather than in total wall area. Lower auxin availability associated with sudden cessation of terminal growth may be responsible for the abrupt springwood-summerwood transition generally observed in this species.

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Pulping Southern Pine Increment Cores by Means of a Small Scale Kraft Procedure

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To facilitate the evaluation of wood and pulp properties on standing trees without endangering the life of the tree, a small-scale kraft pulping technique was devised which was suitable for the preparation of pulps from 10-mm. increment cores. The results obtained from 50 loblolly pines show no significant differences in wood quality between selected trees and their check trees. Since, at the same time, considerable tree-to-tree variation in wood and pulp properties is apparent, selection for wood quality might be quite fruitful and should be carried out in addition to the selection for growth rate and form. A multiple regression analysis showed that yield is strongly influenced by the per cent alcohol-benzene extractives and the per cent lignin, but that the influence of the per cent summerwood is negligible. Zero-span tensile strength is correlated with fiber length and formation but appears independent of the lignin content and the yield.

In the last ten years many advances have been made in forest tree improvement, both in the clarification of the objectives and in the techniques needed to achieve the aims. Growth rate, form, and disease resistance were the initial characters which appeared amenable to improvement and of genuine importance regardless of the end use. Gradually as details regarding the requirements for particular end uses [Bethel (*1*), Watson and Hodder (*2*)], became available, further refinements became of interest to programs engaged in pulpwood improvement. Other characters such as specific gravity, per cent summerwood, fiber-wall thickness, fiber length, fibrillar angle, and chemical composition, were added to the list of improvement goals [Dadswell and Wardrop (*3*), Dadswell, Watson, and Nicholls (*4*), Mitchell and Wheeler (*5*), and Zobel (*6*)]. None of these is, however, a direct test of the pulp yield and quality which can be obtained from particular trees. It seemed, therefore, desirable to develop a method for the preparation and testing of small pulp samples, which can be obtained from a living tree without doing any immediate damage. Large increment cores provide an excellent means for obtaining such samples, and existing pulping procedures were adapted for the preparation of very small quantities of pulp and the performance of a limited number of tests on these pulps. Similar procedures have been developed elsewhere, e.g., by Jayme and Koburg (*7*), and Watson (*8*).

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THE SMALL-SCALE PULPING PROCEDURE

Prior to pulping, the cores were divided lengthwise into two parts, a 20% portion, which was used for chemical analyses, and the remaining 80%, which was pulped. The division was made by mounting the core in a special holder leaving one fifth protruding from the holder and removing this part with a guillotine paper trimmer (Fig. 1). The core was mounted in such a way that the cut was parallel to the grain of the wood. On the 20% fraction of the cores reserved for this purpose, the per cent alcohol-benzene extractives and the per cent lignin were determined following TAPPI Standards T 6 m-54 and T 13 m-54. The remaining portion of the cores was broken into approximately $^1/_2$ in. long pieces and air-dried to constant weight in a room maintained at 73°F. and 50% R.H.

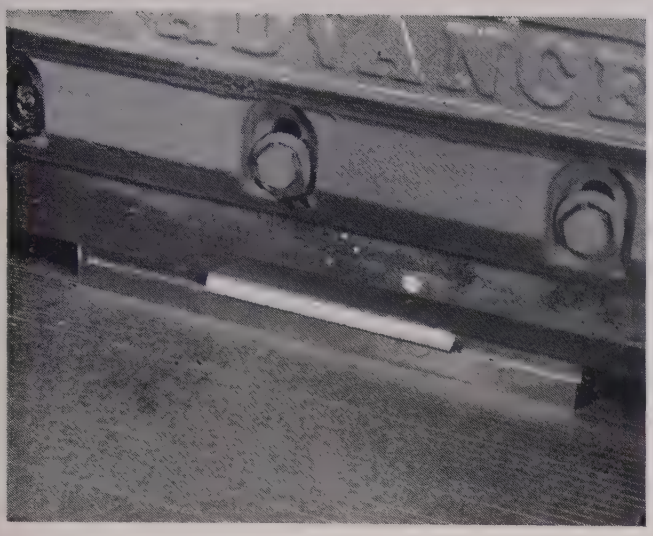

Fig. 1. Core-holding jig and paper trimmer in position for the division of an increment core

The pulping operation was carried out in a battery of seven digesters which tumble end over end in an electrically heated oil bath (Fig. 2). Each vessel holds 410 ml. of water at 20°C. The cooking conditions are given in Table I. At the end of the cooking period the seven vessels were removed as nearly simultaneously as possible to a large tub of cold water and allowed to cool for 10 min. A more detailed description of the procedure is given by Thode, *et. al* (*9*). The covers were then removed and the contents of each vessel were transferred to a 5-l. battery jar where tap water was added to a total of 4 l. The pulp was subsequently defibered and dispersed by a 1/8-hp. Lightnin' stirrer. The water was removed by suction through a Büchner funnel and the defibered pulp

Table I. Cooking Conditions

Maximum temperature, °C.	172
Time from 132 to 172°C., min.	60
Time at 172°C., min.	105
Liquor concn., g.p.l. as NaOH	40.0
Sulfidity, %	15.2
Liquor-to-wood ratio	12.0

thoroughly washed to remove all of the spent cooking liquor.

Determinations made on the pulp included fiber length, yield, and permanganate number. The fiber lengths presented are the arithmetic averages of 300 fibers, excluding the fines. In order to be able to relate the fiber lengths to handsheet properties, all fibers, even those cut or broken, were included in the measurements.

From the pulp, handsheets were prepared on which zero-span tensile strength, basis weight, caliper, and apparent density were determined.

The zero-span tensile strength was included in the measurements as an estimate of the fiber strength. It is determined on the Instron universal testing instrument or the Schopper tensile strength tester, using a special set of jaws, which clamp together with extremely close tolerances. Both jaws, therefore, are clamped on the same fibers and thus a measure of fiber strength is obtained. The technique is described in detail by Wink and Van Eperen (*10*).

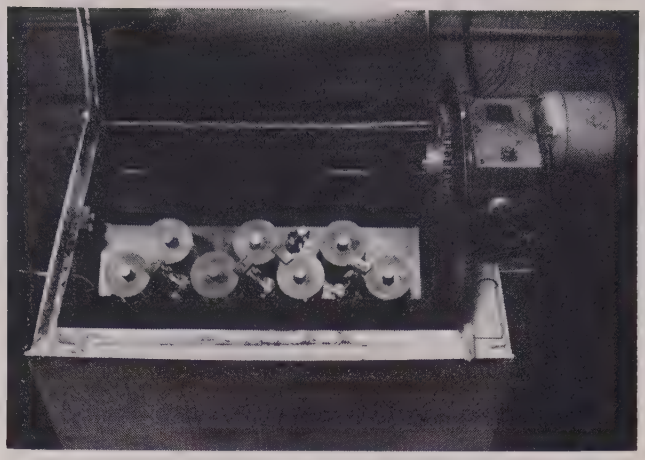

Fig. 2. Multi-digester assembly

RESULTS OBTAINED ON A NUMBER OF LOBLOLLY PINES

The technique outlined above has been applied to well over a hundred southern pine samples. The data presented here were derived from a study comparing a number of selected loblolly pines with their corresponding check trees.

They were selected as part of the North Carolina State Tree Improvement Program and made available for this study through the co-operation of the West Virginia Pulp and Paper Co., the Riegel Paper Corp., and the North Carolina State Tree Improvement Program.

Twenty-five of the trees were sampled on West Virginia Pulp and Paper Co. lands. They were growing in five locations, each of which was sampled by taking one selected tree and four of its neighboring check trees. Wood samples were removed by means of a 10-mm. increment borer. The cores were positioned at breast height forming 90° angles with each other. On the intact cores, the per cent summerwood was determined. The cores were then subjected to the micropulping procedure described earlier. The results are given in Table II. Similarly, 25 other loblolly pines were sampled on Riegel Paper Corp. lands. The results of the determinations made on these cores are presented in Table III.

In Tables IV and V a comparison of the selected and check trees is given together with their variances and tests of significance. A careful examination of the comparison between selected and check trees does not reveal any significant differences between these two groups. All differences appear to be well within the normal range of variation. In a sense, this result is good, for it means that selection for growth rate and form does not have an adverse effect on wood quality. It also means, however, that improved wood quality can be achieved only by selection for this specific purpose. This result is in agreement with earlier findings for specific gravity in slash pine reported by Perry and Wang (*11*).

A number of correlation coefficients between the various properties were calculated, the most important of which are presented in Table VI. As can be seen, pulp yield appears to be strongly influenced by the per cent lignin and the per cent extractives in the wood. The amount of summerwood also seems to have some

Table II. Selected Loblolly Pines and Check Trees of the West Virginia Pulp and Paper Co.
Wood and Pulp Quality Data Obtained from Breast Height Increment Cores

Tree number	*Number of annual rings at breast height*	*Alcohol-benzene extractives, %*	*Lignin, %*	*Permanganate number*	*Yield, %*	*Basis weight*	*Caliper*	*Apparent density*	*Zero-span tensile strength, lb./in.*	*Summerwood, %*	*Fiber length, mm.*	*Thwing formation, units*
11-9	21	11.4	28.3	22.8	40.4	48.4	6.3	7.7	37.5	41	1.74	44.4
11-9-1		10.0	28.8	23.2	41.0	46.0	6.0	7.7	42.1	39	2.15	39.0
11-9-2		7.3	29.4	23.8	41.4	47.3	6.2	7.6	42.3	48	2.02	43.1
11-9-3		6.9	28.0	23.6	43.6	46.1	6.6	7.0	46.8	52	1.92	41.3
11-9-5		10.6	29.0	19.7	39.0	47.3	5.8	8.2	38.9	33	1.99	51.3
11-10	20	9.2	28.0	21.2	40.0	46.0	6.2	7.4	43.5	38	1.99	38.8
11-10-1		6.2	28.0	19.8	42.6	46.0	6.0	7.7	47.5	42	2.08	43.8
11-10-2		8.0	27.9	20.7	40.4	47.4	6.3	7.5	41.1	42	1.95	46.5
11-10-3		7.05	28.8	22.6	41.9	47.2	6.1	7.7	42.5	35	1.89	47.3
11-10-4		9.8	29.4	23.4	38.8	48.4	6.8	7.1	36.9	44	1.86	50.5
11-14	43	4.4	27.3	25.5	47.1	47.0	7.3	6.4	48.0	48	2.31	30.0
11-14-2		8.1	26.8	18.8	42.1	46.0	6.3	7.3	51.2	50	2.41	34.4
11-14-3		5.2	27.6	20.5	44.4	47.4	6.3	7.5	48.9	59	2.41	37.1
11-14-4		5.1	28.4	23.0	43.5	47.2	6.4	7.4	44.6	51	2.02	36.3
11-14-5		5.3	28.0	18.7	43.1	45.8	6.0	7.6	47.2	50	2.45	36.3
11-16	44	6.4	28.8	22.4	43.0	46.9	6.6	7.1	52.8	56	2.38	34.9
11-16-2		7.0	27.0	18.9	43.7	45.3	6.3	7.2	49.1	50	2.52	31.6
11-16-3		7.9	28.2	22.3	41.0	46.4	6.5	7.1	51.3	47	2.50	34.3
11-16-4		5.3	27.2	20.4	44.1	47.1	6.0	7.8	45.4	49	2.33	37.3
11-16-5		6.2	27.7	18.6	43.3	45.2	6.5	7.0	53.9	51	2.38	33.2
11-18	44	9.1	28.2	19.7	42.1	47.8	7.0	6.8	50.3	48	2.71	35.7
11-18-1		6.5	27.4	18.6	42.4	44.9	6.3	7.1	44.6	51	2.31	33.3
11-18-2		4.5	27.5	20.4	43.9	47.0	6.9	6.8	47.3	54	2.57	34.2
11-18-3		9.4	27.5	21.5	42.8	45.6	6.4	7.1	48.5	46	2.33	32.1
11-18-4		4.7	27.5	22.3	45.1	46.3	6.0	7.3	39.1	48	2.30	35.2
Average		7.3	28.0	21.3	42.4	46.6	6.4	7.3	45.7	46.8	2.22	38.5
Standard deviation		2.0	0.71	1.9	1.9	0.9	0.4	0.4	4.8	6.3	0.26	6.0

influence. To investigate these mutual relationships further, a calculation of the multiple regression equation was made and is presented in Table VII. From this it is obvious that lignin and extractives content are the two most important factors related to yield while the per cent summerwood is of little importance when it is considered in combination with these two other factors.

The zero-span tensile strength is strongly influenced by fiber length and formation and to a much lesser extent by the per cent lignin and the yield. A calculation of the multiple regression equation shows that fiber length and formation remained the two most important factors related to zero-span tensile strength while the per cent lignin and the yield apparently only have an influence because of their correlation with fiber length and formation (see Table VIII).

DISCUSSION

One of the most gratifying results obtained in this study is the wide range of variation found in several properties of economic importance such as the alcohol-benzene extractives and yield. The zero-span tensile strength is showing large variation from tree to tree

Table III. Selected Loblolly Pines and Check Trees of the Riegel Paper Corp.
Wood and Pulp Quality Data Obtained from Breast Height Increment Cores

Tree number	*Number of annual rings at breast height*	*Alcohol-benzene extractives, %*	*Lignin, %*	*Permanganate number*	*Yield, %*	*Basis weight*	*Caliper*	*Apparent density*	*Zero-span tensile strength, lb./in.*	*Summerwood, %*	*Fiber length, mm.*	*Thwing formation, units*
9-3	27	4.5	27.95	22.4	42.4	45.8	6.4	7.2	53.4	39	2.27	40.7
9-3-1		5.8	30.7	22.1	39.8	44.8	5.0	9.0	37.0	46	1.93	49.0
9-3-2		6.4	28.4	19.6	43.1	45.4	5.7	8.0	50.2	48	2.40	45.0
9-3-3		4.9	28.1	22.4	43.9	45.0	6.2	7.3	47.8	53	2.24	37.9
9-3-4		6.8	28.8	21.4	39.5	46.1	6.0	7.7	45.7	43	2.01	45.2
9-4	18	8.7	29.9	18.5	38.4	45.4	5.2	8.7	36.0	43	1.85	50.4
9-4-1		9.8	29.05	20.1	41.1	46.2	5.7	8.1	42.1	41	1.72	46.2
9-4-2		5.6	28.9	20.6	41.2	46.0	5.2	8.8	43.9	35	1.93	48.3
9-4-4		5.9	29.1	20.6	40.7	46.2	5.6	8.2	45.4	32	1.98	45.0
9-4-4A		4.0	28.2	24.0	40.6	46.3	5.4	8.6	39.2	51	2.03	45.5
9-9	40	4.3	29.7	21.8	41.3	44.0	5.5	8.0	53.9	44	2.37	40.8
9-9-3		6.0	28.3	20.2	41.4	45.4	5.6	8.1	46.4	42	2.17	46.0
9-9-4		5.4	26.8	22.4	42.5	44.9	6.3	7.1	57.4	44	2.24	33.1
9-9-5		4.7	30.4	20.0	42.4	44.1	6.0	7.4	59.7	42	2.38	36.3
9-9-6		9.9	28.4	19.4	41.2	45.3	6.0	7.6	59.9	40	2.25	47.3
9-10	40	7.8	27.6	19.6	42.6	44.5	5.8	7.7	59.9	43	2.42	33.2
9-10-1		5.5	27.9	22.4	41.5	43.8	5.7	7.7	58.4	42	2.46	34.7
9-10-2		5.9	28.9	21.8	41.5	46.1	6.5	7.1	54.6	42	2.30	41.1
9-10-3		18.5	27.45	21.6	30.6	45.2	7.0	6.5	54.9	45	1.97	35.7
9-10-5		8.5	28.0	22.9	40.9	45.9	6.3	7.3	51.9	44	2.09	42.3
9-17	33	8.5	28.8	21.5	41.3	46.7	6.6	7.1	46.5	37	2.05	44.7
9-17-1		7.6	28.7	20.6	40.2	46.5	6.1	7.6	47.3	37	2.02	48.2
9-17-2		10.2	28.5	21.1	38.2	46.2	6.4	7.2	51.4	37	2.10	47.2
9-17-4		9.9	28.7	21.2	38.7	46.1	6.3	7.3	48.9	34	2.05	47.0
9-17-5		5.1	27.4	20.4	43.0	46.4	6.4	7.2	43.7	47	2.17	44.2
Average		7.2	28.6	21.1	41.0	45.5	6.0	7.7	49.4	41.8	2.13	43.0
Standard deviation		3.0	0.94	1.3	1.5	0.8	0.5	0.6	7.0	5.0	0.19	5.2

Table IV. Comparison Between Selected Loblolly Pines and Check Trees of the West Virginia Pulp and Paper Co.

	Selected trees	*Check trees*	*MS Selected vs. check trees*	*MS error*	*F*
Alcohol-benzene extractives, %	8.1	7.1	4	2.89	1.38
Lignin, %	28.1	28.0	0.04	0.371	0.108
Permanganate number	22.3	21.0	6.76	3.612	1.87
Yield, %	42.5	42.4	0.04	2.46	0.016
Basis weight, lb.	47.2	46.5	...	..	..
Caliper	6.7	6.3	...	..	..
Apparent density	7.1	7.4	...	..	..
Zero-span tensile strength	46.4	45.5	3.24	13.29	0.24
Summerwood, %	46	47	4	22.72	0.18
Fiber length, mm.	2.23	2.22	0.0004	0.022	0.018
Thwing formation, units	36.8	38.9	17.64	10.79	1.63

$F_{0.05} = 4.38$.
$F_{0.01} = 8.18$.

Table V. Comparison Between Selected Loblolly Pines and Check Trees of the Riegel Paper Corp.

	Selected trees	*Check trees*	*MS Selected vs. check trees*	*MS error*	*F*
Alcohol-benzene extractives, %	6.8	7.3	1.00	9.24	0.108
Lignin, %	28.8	28.6	0.16	1.04	0.154
Permanganate number	20.8	21.2	0.64	1.83	0.350
Yield, %	41.2	41.0	0.16	2.24	0.071
Basis weight, lb.	45.3	45.6	..	...	..
Caliper	5.9	6.0	..	...	..
Apparent density	7.7	7.7	..	...	..
Zero-span tensile strength	49.9	49.3	1.44	21.48	0.067
Summerwood, %	41	42	4.0	23.33	0.171
Fiber length, mm.	2.19	2.12	0.0196	0.0219	0.895
Thwing formation, units	42.0	43.3	6.76	16.53	0.409

$F_{0.05} = 4.38$.
$F_{0.01} = 8.18$.

Table VI. Correlations Between Various Significant Wood and Pulp Properties

Variables		*Correlation coefficients*
Yield, %	Alcohol-benzene extractives, %	−0.66
Yield, %	Lignin, %	−0.36
Yield, %	Summerwood, %	0.29
Alcohol-benzene extractives, %	Lignin, %	−0.035
Alcohol-benzene extractives, %	Summerwood, %	−0.29
Lignin, %	Summerwood, %	−0.115
Zero-span tensile strength, lb./in.	Lignin, %	−0.16
Zero-span tensile strength, lb./in.	Yield, %	0.22
Zero-span tensile strength, lb./in.	Fiber length, mm.	0.54
Zero-span tensile strength, lb./in.	Thwing formation, units	−0.47
Lignin, %	Fiber length, mm.	−0.03
Lignin, %	Thwing formation, units	0.38
Yield, %	Fiber length, mm.	0.27
Yield, %	Thwing formation, units	−0.46
Fiber length, mm.	Thwing formation, units	−0.29

$r_{0.05} = 0.325$. $r_{0.01} = 0.418$.

Table VII. Multiple Regression of Yield on Extractives Content, Lignin Content, and Summerwood Percentage

Standard Partial Regression Coefficients

Yield on extractives content	−0.66
Yield on lignin content	−0.38
Yield on summerwood percentage	0.06

Multiple Correlation Coefficient

$R = 0.765$

Table VIII. Multiple Regression of Zero-Span Tensile Strength on Lignin Content, Yield, Fiber Length, and Formation

Standard Partial Regression Coefficients

Zero-span tensile strength on lignin content	−0.06
Zero-span tensile strength on yield	−0.08
Zero-span tensile strength on fiber length	0.46
Zero-span tensile strength on formation	−0.36

Multiple Correlation Coefficient

$R = 0.636$

but, at present, its economic importance is not fully known. Since fiber strength is only one of the factors influencing sheet strength, and fiber length and fiber bonding also make a significant contribution, it is not possible to predict how well this measurement will be correlated with the other measurements of sheet strength. A number of studies are under way to gain additional information about these relationships.

Differences in yield of the order of magnitude indicated by these results are economically highly important. It should, however, be kept in mind that they pertain to increment cores and need to be confirmed by studies of the relation between the data obtained on increment cores and the actual wood and pulp properties of the whole trees. If positive results are obtained on this second study, a beginning can be made with the application of pulping to tree improvement by including these measurements in the evaluation of selected trees and by their inclusion in heritability studies.

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So many of the past and present Institute staff members have contributed to the development of the small sample pulping procedure, that it seems impossible to thank each one individually. A special word of appreciation is deserved by John Peckham and the staff of the Pulping Laboratories, Engineering and Technology Section, for their painstaking work in the preparation of the pulp samples and the performance of the chemical analyses. The authors are also much indebted to W. Wink and the members of the Paper Evaluation Section for testing the handsheets. Finally, they wish to acknowledge the efforts of Mrs. W. Olson, who measured some 15,000 fibers during the course of this investigation.

A Biological Basis for Sampling in Studies of Wood Properties

S. D. RICHARDSON

Some patterns of variation in internodal ring width, wood density and tracheid length within single trees are described. Some of the variation appear to be inherent and some are environmentally determined. It is argued that for the successful evaluation of wood properties, the establishment of inherent variation patterns is a prerequisite; and that systematic sampling based on knowledge of these patterns is more appropriate than either random or absolute-height sampling.

THE existence of variation in wood properties within a tree is well established and it forms a major obstacle to the evaluation of timber for specific purposes. This is particularly true with regard to anatomical features, where the variation within the tree is often greater than that between trees of the same species grown under similar conditions; consequently, in studies designed to assess the effects of different growth conditions or to compare different genotypes, the method of sampling employed is of paramount importance.

In the evaluation of timber properties it is usual either to examine samples removed from the tree at a fixed height above ground level (usually breast height), or to take a series of samples at equidistant points along the stem, or at points which represent fixed percentages of the total stem length (e.g., 10, 20, 30% etc., of the tree height). This approach is, essentially, statistical and takes virtually no account of possible variations in growth pattern within and between trees. In the present paper an attempt will be made to demonstrate that for the precise assessment of relatively small differences such an approach may be less appropriate than one based on an appreciation of the tree as a biological entity rather than a statistical population of tissues.

VARIATION IN RING WIDTH WITHIN TREES

The annual ring forms a starting point for most investigations in wood anatomy and it is surprising, therefore, that there have been few critical studies of growth distribution throughout the tree. Recently, one of our students, A. J. Low (*1*) following the methods used by Duff and Nolan (*2, 3*), measured ring widths in disks cut at the center point of every internode in a series of trees. Figure 1 illustrates his complete data for one tree of Corsican pine. It is in the form of a diagram showing individual ring widths by internodes.

There are three ways in which these data can be plotted on conventional time scales. Following Duff and Nolan's terminology (*2, 3*), the first "sequence" is that in which changes in ring width within each single ring are followed from the top of the tree downwards; in the second sequence, ring widths in successive rings are plotted from the pith outwards within each internode; and, in the third sequence, ring widths are plotted for successive internodes down the tree, but at a constant ring number from the pith (i.e., rings formed by cambia of approximately the same ages). These three sequences are illustrated in Fig. 2, where eight series of ring widths are plotted in the ways just described.

The first sequence shows a systematic pattern of variation, in that ring width increases rapidly to about the fifth internode from the apex, and then decreases gradually towards the base of the ring, finally losing any appearance of systematic pattern. Sequence 2 (variation from the pith outwards across the internodal disks) is essentially similar. In both sequences, non-systematic variation is indicated by the extent to which the plotted points depart from a smooth curve and is what Duff and Nolan term "configuration" (*2, 3*). It is masked, however, by the distinct patterned variation. In sequence 3, on the other hand, in which ring widths are plotted for successive internodes down the tree, but at a constant number of rings from the pith, there is no evidence of systematic pattern, and, particularly in the later-formed rings (to the left of the graph), the effects of the year of formation on ring width are brought into strong relief.

Low has further shown that variation in the third sequence can be causally related to climatic conditions at the time of ring formation and is also correlated with extension growth. Any attempt to obtain similar correlations from sequences 1 and 2, however, failed because the systematic variation was such as to hide the effects of environment on growth rate.

From a comparison of these and other data for Corsican pine growing in Scotland with those of Duff and Nolan (*2, 3*) for red pine in Canada, it seems that the patterns revealed by the first two sequences are inherent characteristics of tree growth, though there may be specific quantitative differences. It follows that, in attempts to relate ring-width variation to one or other of the many environmental factors which affect increment, or to compare genotypes, it is essential to recognize and allow for this systematic variation. It also follows that similar allowance must be made in studies of anatomical features which may be related to growth rate (as, for example, wood density and tracheid length).

VARIATION IN WOOD DENSITY

Figure 3 shows complete internodal sampling of Corsican pine for basic density (dry weight/saturated volume) averaged for two radii in each ring, while in

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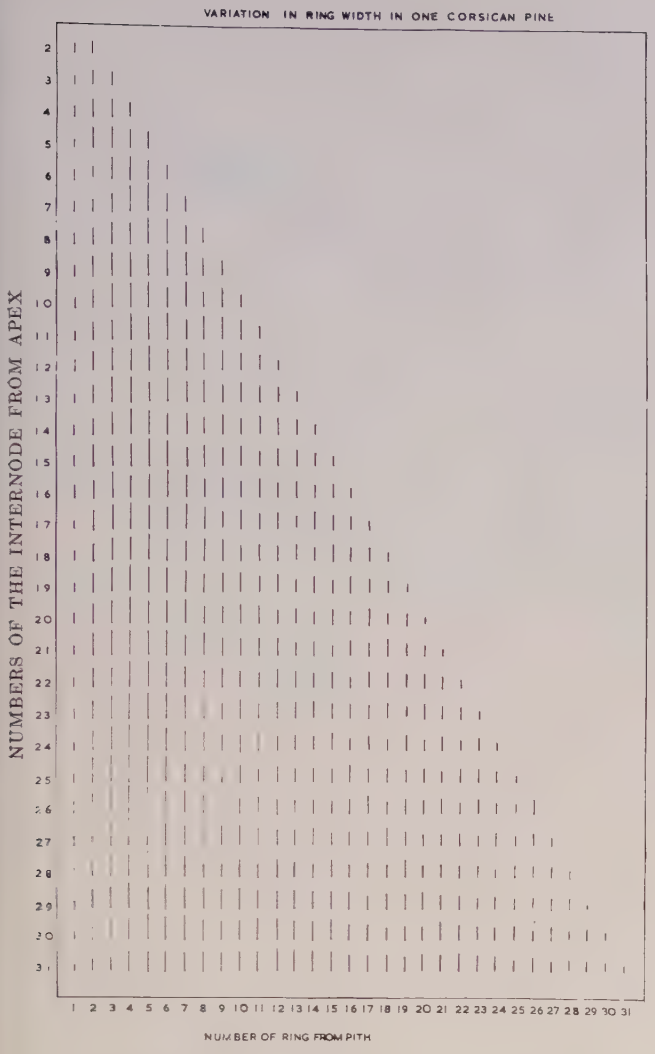

Fig. 1. Corsican pine. Histogram showing relative ring-width distribution in one tree 31 yr. old

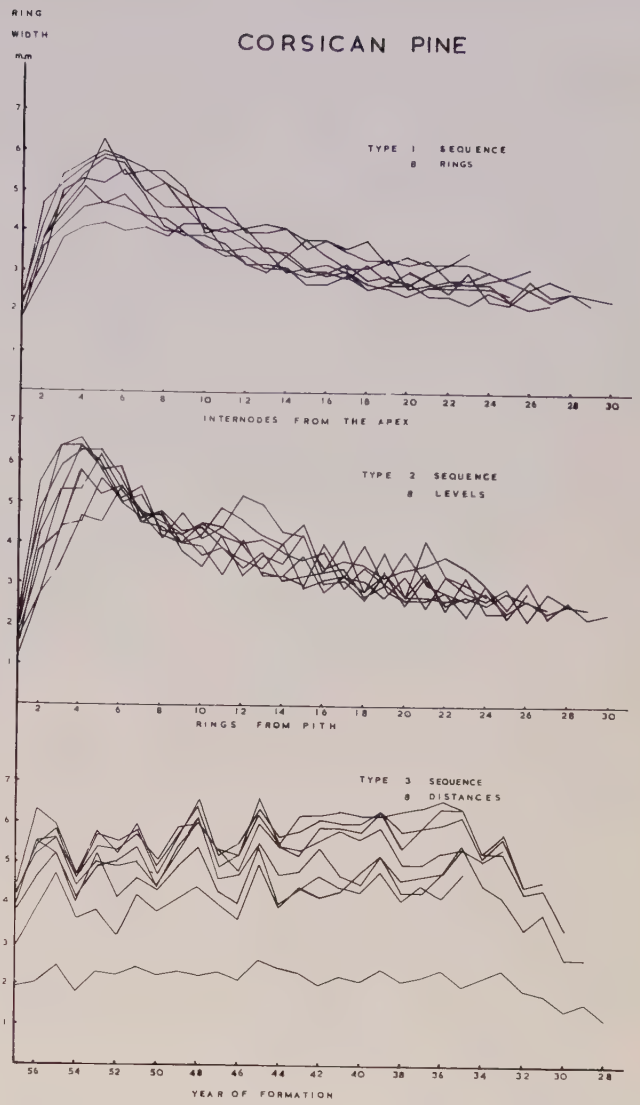

Fig. 2. Corsican pine. Eight series of ring widths plotted according to Duff and Nolan's sequence types (2)

Fig. 4 the three sequences are illustrated as before. Again, there are two systematic patterns within the tree and one unsystematic, though there are obvious differences between the density patterns and the ring-width patterns. Thus, within any one ring traced downwards from the apex of the tree (sequence 1), the density pattern is almost the converse of that revealed by ring-width variation; density first of all decreases to a minimum at about the fifth internode from the apex and then increases to the twentieth. Beyond the twentieth internode in any one growth sheath, there would appear to be no systematic variation. At any one level (sequence 2), density is high in the first ring from the pith, falls steeply to a minimum around the sixth ring and then increases outwards; again, variation in the outermost rings is less systematic than in the center. This latter pattern is well known to wood technologists, since it is this sequence which is usually examined in studies of wood density. There are reported differences, however, in the rate of the increase outwards and in the point at which density becomes maximal. Such differences may be specific or they may be related to environment.

Wood density traced through successive internodes down the tree but at a constant ring number from the pith (sequence 3) shows no systematic variation. However, the curves have certain similarities in configuration which, as with ring width, can be correlated with climatic conditions.

It has also been shown that, in any one ring, wood density measured near the nodes shows consistently greater variation than at the center of the internode.

VARIATION IN TRACHEID LENGTH

Another of our students, J. M. Dinwoodie (*4*), has carried out complete internodal sampling for tracheid length on several trees of plantation-grown Sitka spruce, measuring 50 tracheids from the first few rows of cells in each ring. His data are illustrated in Fig. 5, while Fig. 6 shows typical examples of each of the three sequences. Within any one ring traced downwards from the apex (sequence 1) tracheid length increases steadily up to the sixth internode and then remains relatively constant or decreases slightly at the base of the tree. A systematic pattern is not apparent after about the ninth internode.

At any one level (sequence 2) tracheids near the pith are short but the length increases with increasing ring number from the pith. This sequence is also distinctive in that in the lower internodes (longest sequences) tracheid length increases relatively slowly; in successive internodes up the tree the rate of increase becomes progressively greater. As with density, this sequence is

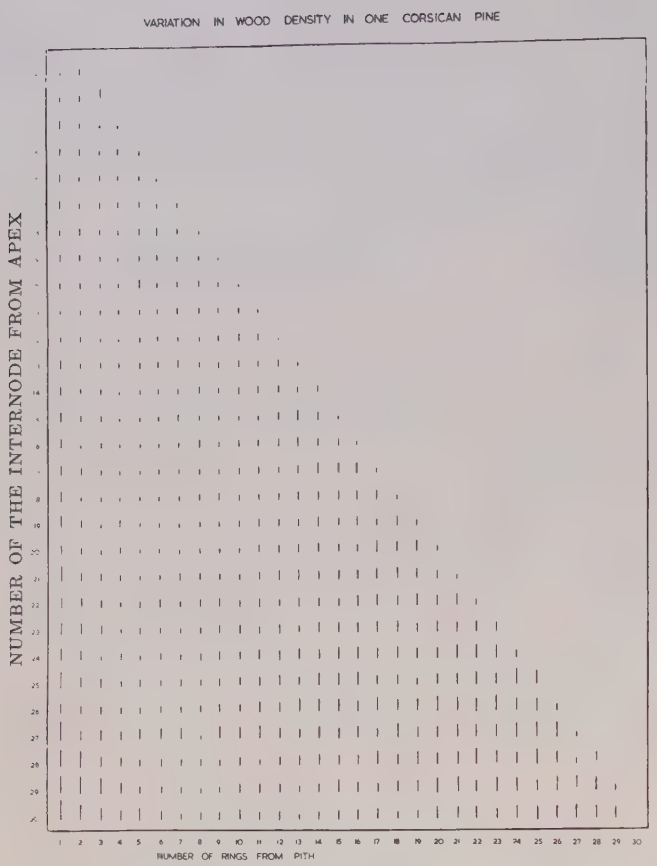

Fig. 3. Corsican pine. Histogram showing relative wood density distribution in one tree 30 yr. old

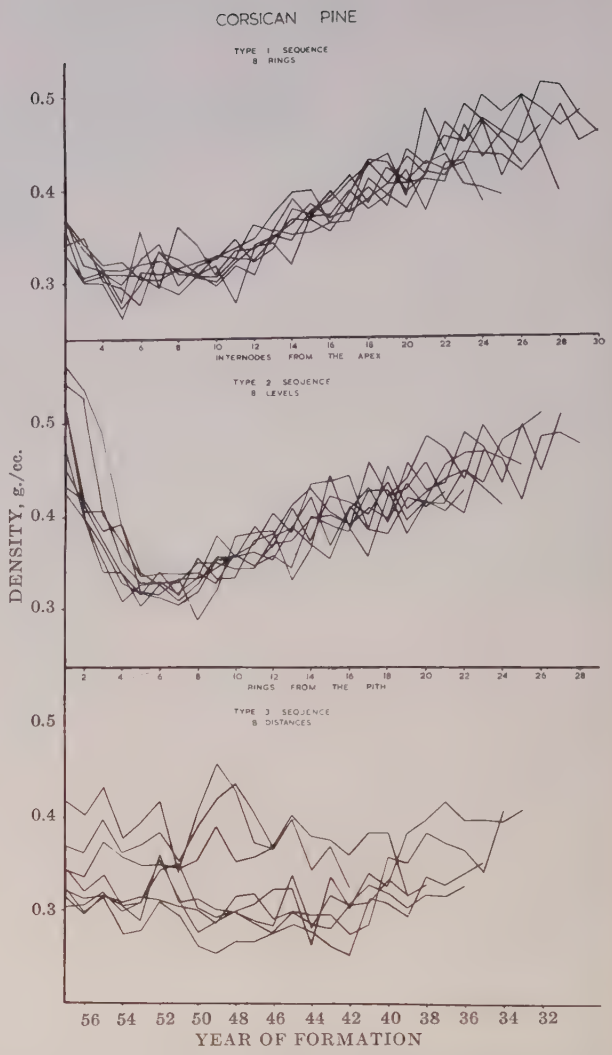

Fig. 4. Corsican pine. Eight series of wood density measurements plotted according to Duff and Nolan's sequence types (2)

well authenticated in the literature. The first sequence is also known, though it has not previously been established on an internodal basis.

Finally, when traced through successive internodes down the tree at a fixed distance from the pith (sequence 3), tracheid length shows no systematic variation in rings near the pith, though there is some evidence of the emergence of a pattern further out, where tracheid length decreases along the time scale. The length variation in rings next to the pith can be significantly correlated with height growth of the tree (correlation coefficient = 0.824 in this case).

THE IMPLICATIONS OF VARIATION FOR SAMPLING PROCEDURE

These systematic patterns of variation in ring width, wood density, and tracheid length have been confirmed repeatedly; and some progress has been made in elucidating the physiological bases on which they rest (*5, 6*). The present purpose, however, is not to attempt to explain variation, but to discuss its implications with regard to the design of sampling procedures for comparative purposes. The object of such sampling is not to evaluate the entire tree, but to obtain representative values which can be used to relate individual stem properties to the species norm or to compare the effects of silvicultural treatments, etc.

In the first place, it is important that samples should be taken, as far as possible, from the center of the internodes. Greater anatomical variability near the nodes is well established and, with respect to density at any rate, it is found in rings formed long after branch abscission.

Secondly, because there is systematic variation within the tree in ring width, wood density, and tracheid length (and probably in other properties also), it follows that random sampling is inappropriate. Sampling must be systematic and based on a knowledge of the inherent variation patterns for the species. The establishment of these patterns must be regarded as a prerequisite for successful sampling. If sampling is to be carried out by means of internodal disks or increment cores, these should be located with reference to the number of internodes from the apex of the tree and not according to their position above ground, a contention which is supported by the physiological evidence that anatomical variation relates directly or indirectly to the activity of the apical meristem (*7*).

Failure to realize that patterned variation in wood properties stems from the terminal shoot may result in misleading conclusions. For example, if disks are taken from two series of trees at the same height above ground level, slight differences between the two in the pattern of early height growth will give disks comprising different numbers of rings. A comparison of the density variation from the pith outwards can give consistent (and statistically highly significant) differences between the two series of the order of 15 to 20%. If they are known to be distinct genotypes it might be concluded, from evidence of this sort, that density is subject to direct genetic control. The conclusion may

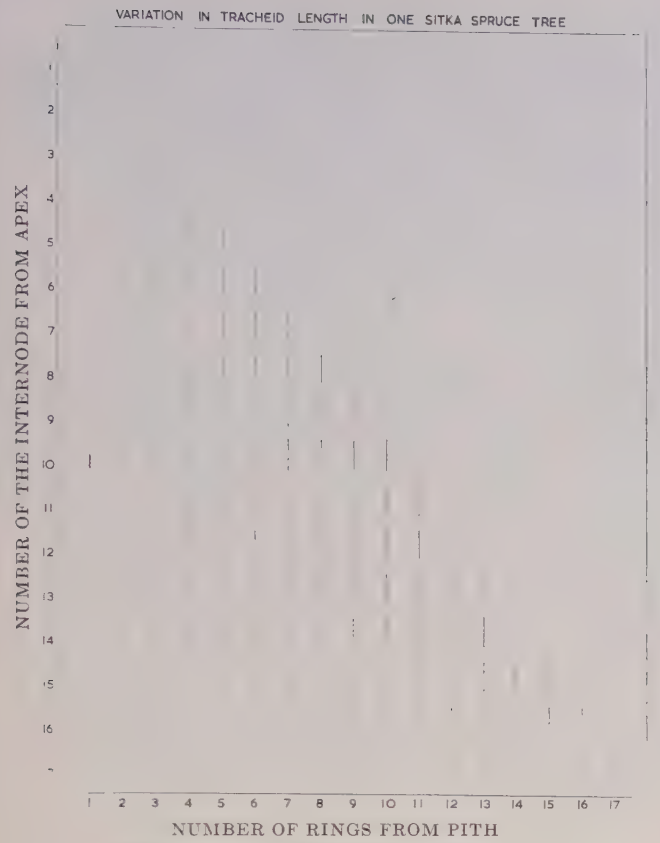

Fig. 5. Sitka spruce. Histogram showing relative tracheid length distribution in one tree 18 yr. old

well be a correct one, but, in the example cited, the observed differences could equally well be due to the location of the two sets of samples in different internodes relative to the apex.

It can be objected that, in mature trees, all the internodes cannot be recognized externally and the location of internodal samples relative to the apex is impossible without exhaustive stem analyses. In such a case, samples from the recognizable internodes should be supplemented by disks or increment cores taken at heights which represent fixed percentages of the total stem height rather than at absolute levels, since this will in part allow for patterned variation of the first sequence type. Second-order sampling within the disks should recognize the variation pattern of the second sequence. Thus, within the zone of systematic variation, samples from different trees should be compared at a constant number of rings from the pith. Outside this zone, comparisons should be made according to the chronological year of ring formation (i.e., at a constant number of rings from the bark).

Finally, the data discussed in the present paper demonstrate that systematic variation in density and in tracheid length have little in common. It follows from this that the same sample distribution cannot be used for the assessment of both features, unless the variation patterns are first established. It also suggests that other features will have different patterns, and that Duff and Nolan's (*2, 3*) method of analysis may be a prerequisite for the successful evaluation of other wood properties.

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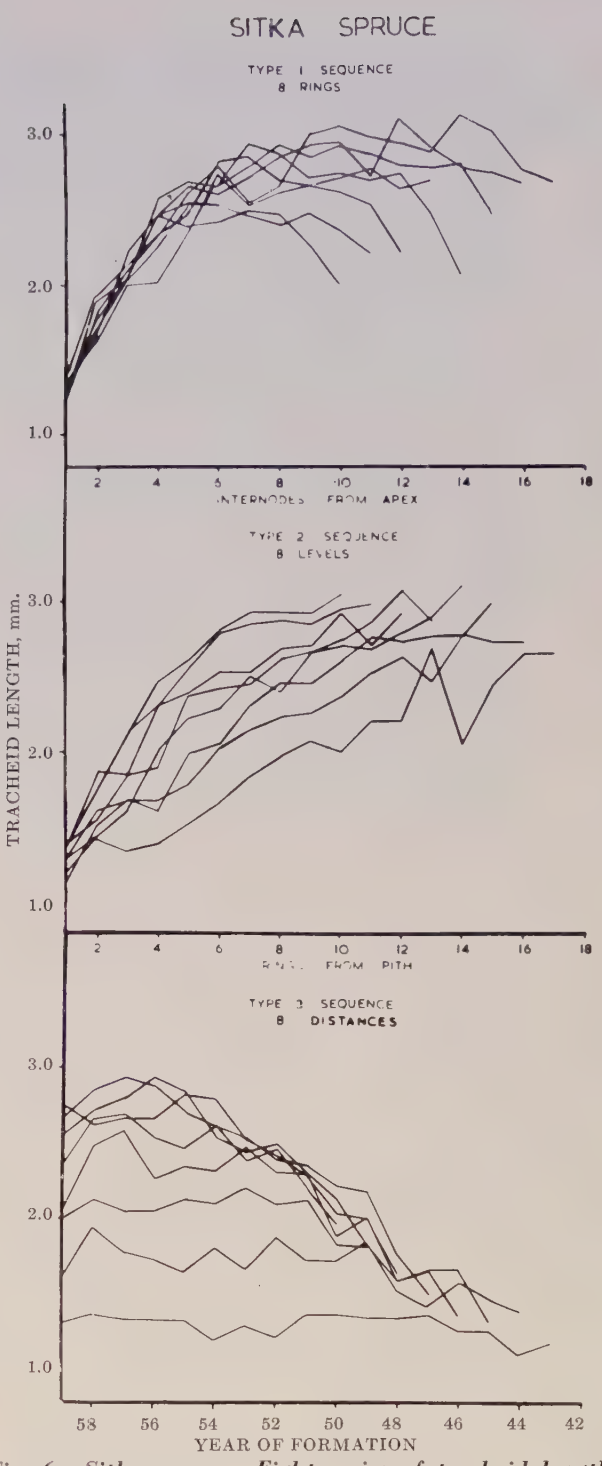

Fig. 6. Sitka spruce. Eight series of tracheid lengths plotted according to Duff and Nolan's sequence types (2)

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Tree-to-Tree Variations and the Gross Heritability of Wood Characteristics of *Pinus radiata*

H. E. DADSWELL, J. M. FIELDING, J. W. P. NICHOLLS, and A. G. BROWN

A preliminary account is given of studies being conducted on variations in wood characteristics of *Pinus radiata* D. Don. Topics discussed are: the gross heritability of percentage late wood, basic density, tracheid length, longitudinal shrinkage, spiral grain, percentage cellulose, and ring width. Estimates of correlations between certain of these characteristics are also given. The estimates of gross heritability and of the correlations were made on samples from a clonal plantation: in addition, estimates are given of the gross heritability of four of the characteristics by a method using both clonal and seedling trees. In the material concerned gross heritability of percentage late wood, basic density, and tracheid length was found to be relatively high, that of percentage cellulose, low. The investigations are to be continued using material from clonal plantations and seedling progeny tests.

A STRIKING feature of the *Pinus radiata* plantations in Australia and New Zealand is the great variation shown in the external, morphological, characteristics of the trees. This variation is due to the differences among the various trees resulting from two factors: their heredity and the environment under which they have developed. That heredity plays a very important role is obvious to any observer visiting a plantation of clones*. He is immediately struck as much by the large differences between clones as by the uniformity within each clone. This is shown clearly in Figs. 1 and 2.

Gross heritability values for such external characteristics as tree height, stem girth, stem taper, crown diameter, angle of branching, and bark thickness, were estimated by Toda (*1*) on clone material of *Cryptomeria*. Working with *P. radiata*, Fielding (*2*) has shown that in clonal plantations in the Australian Capital Territory the gross heritability of a number of external features is high. There is thus good reason to expect that valuable improvements in the external form of the species can be effected by the proper selection for branch angle, internode length, etc., and breeding for selected features.

The next point to consider is the extent to which desirable wood characteristics are transmitted from parent to progeny, because after all, it is the wood that will be used. Firstly, however, it is necessary to know what wood characteristics are important, and this question has been answered to some extent (*3*, *4*, *5*). As a result, such features as cell length, basic density, cellulose content, spiral grain, and percentage late wood have been chosen. Each is known to vary considerably within a tree, but each also varies between trees. Knowledge of such variations is of fundamental importance in utilization because of the correlations between basic wood characteristics and wood properties.

As with external tree features, two factors operate in determining wood characteristics, namely heredity and environment. The influence of environment has been studied by numerous workers; but unfortunately, there is relatively little definite evidence of the influence of genetic control, although there is considerable evidence of the wide range of variation between trees in certain wood features. For example, Wardrop and Preston (*6*) and Bisset, *et al.* (*7*) have indicated that initial tracheid length in the first developed growth rings of conifers including *P. radiata* can be markedly different in different trees of a species, and further, that the difference is maintained through successive growth rings. The importance of higher than average tracheid length has been stressed recently (*4*) because of the value of long tracheids in developing certain pulp strength properties, and because of the correlation between cell length and certain wood properties (*8*, *9*). Therefore it is desirable to know whether cell length is, in fact, under strong genetic control because, if so, valuable improvements may possibly be achieved by selecting for long tracheids. The work of Echols (*10*) on slash pine indicated that breeding for long tracheids was genetically feasible; a similar conclusion was reached by Jackson and Greene (*11*).

Zobel and co-workers (*12*, *13*) have stressed the large tree-to-tree variations that occur in the wood density of southern pines and the strong probability that these are due largely to genetic differences. Fielding and Brown (*14*) investigated tree-to-tree variations in the wood density of *P. radiata* in the Australian Capital Territory and made estimates of the heritability of this characteristic. Other wood features have also been investigated from the point of view of improving properties. Nilsson (*15*) discussed the breeding of Swedish trees with the object of producing strains with wood of the most desirable chemical composition. Kennedy and Jaworsky (*16*) have referred to the wide variation in cellulose content in Douglas-fir wood and stressed the desirability of propagating trees with high cellulose content. Champion (*17*) has shown that spiral grain is definitely an inherited wood characteristic. Schreiner (*18*) has referred to those characteristics of wood, which, in his opinion, should be capable of improvement genetically.

However, because of the dearth of definite information on the heritability of various wood features, the investigations outlined in this paper were planned. The main objective was to use clonal material of *P. radiata* to determine gross heritability of such features as cell length, basic density, cellulose content, and

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* A group of individuals derived from the same parent by a sexual reproduction.

Figs. 1 and 2. An illustration of the relative uniformity that exists among the trees of a particular clone in such external, morphological characteristics as crown width and branching, compared with the differences that may exist between clones

Clone 939 shown in Fig. 1 (left) is 9 years of age; clone 493 in Fig. 2 is 6 years old: both clones were raised from cuttings, and are growing in the Hall's Block plantations of the Australian Capital Territory. Although these two clones are not particularly contrasting in type, big differences between them can be seen in the photographs.

Fig. 3. Part of the clonal plantation from which the wood samples were obtained

Several sampled trees are shown. The holes in the trunks resulting from the sampling have been plugged and the outside of each plug has been sealed by a black grafting mastic.

spiral grain. Seedling material of approximately the same age and grown in the same locality was also selected for inclusion in the investigations. It should be mentioned here that after earlier observations by Wardrop (*19*) on the variation of tracheid length between trees of various species, the average tracheid length in twig material from some 2500 trees of *P. radiata* was determined. Clones from selected trees were then established and subsequently it was shown that the tracheid length of the parent was carried over to the progeny.

In the investigation described below, the examination of the wood samples and the necessary measurements were carried out at the Division of Forest Products, C.S.I.R.O., on samples taken from clonal and seedling plantations being grown in the Australian Capital Territory by the Forestry and Timber Bureau of the Department of the Interior.

It is hoped, in the immediate future, to make further estimates of the gross heritability of the same wood characteristics in other clonal plantations, and later, to estimate heritability in its narrow sense in seedling progeny tests which are now beginning to become sufficiently old for this purpose.

MATERIALS AND METHODS

Collection of Specimens

The specimens used in this investigation were obtained from plantations of *P. radiata* in the Australian Capital Territory (see Fig. 3) according to the method of Echols and Mergen (*20*) as modified by the Forestry and Timber Bureau at Canberra (*21*). The trees were

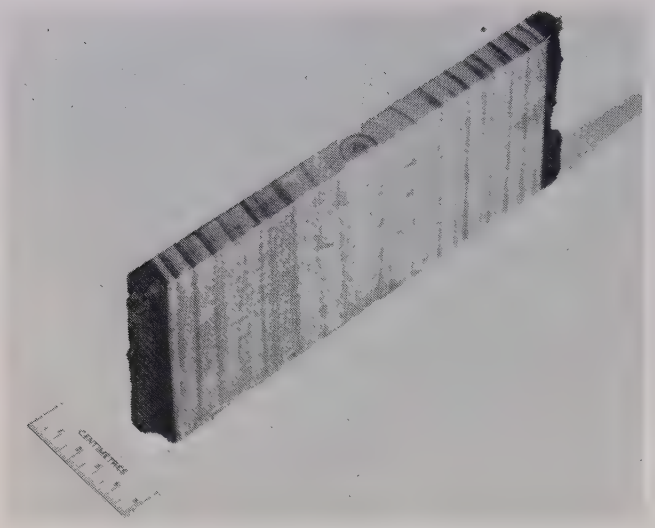

Fig. 4. Typical specimen taken from the live tree for use in the determination of wood characteristics

sampled at about 4 ft. from the ground, the actual height being dependent in each case on the position of the whorls near this level. Each sample was taken in the middle of an internode. Each sample was approximately $^3/_4$ in. wide and 3 in. deep, and it extended from bark to bark through the pith in a north-south direction (see Fig. 4). As soon as it was removed from the tree, each sample was numbered, marked, and placed in water. From then until needed for examination of the wood, it was kept moist. Two stands were sampled:

A Clonal Plantation Established in 1948. The clones comprising this plantation were raised from cuttings collected in 1947 from trees in a 1941 plantation, the seed source of which was New Zealand. The mother trees of the clones were selected for good vigor, form, and branching; they were all multinodal trees. The cuttings were second-order shoots taken from branches at approximately 5 ft. above ground. The rooted cuttings were planted out approximately 15 months after original collection. The clones are thus of identical physiological age. Each was represented in the plantation by 1 to 2 rows of trees. For the present study, two trees were sampled from each of 22 clones (all those available in this plantation). The trees were selected at random—one tree being selected from each of the three trees at the ends of each clone—random sampling was restricted in this way to provide for the two trees in each clone to be separated as far as possible. The clones were not replicated because insufficient trees were available. Figure 5 shows the plan of this clonal plantation, and the positions of the chosen trees.

A Seedling Plantation Established in 1948. This stand immediately adjoins the above clonal plantation. It was established with open-root seedlings approximately 9 months old. The seed source is unknown. Sampling was carried out on 29 trees growing in one row in this stand to supplement information obtained from the clonal plantation and particularly to obtain more data on tree-to-tree phenotypic variation. The trees were selected in order in the row, only those trees with obvious bends at the height of sampling being rejected. The first tree was selected by position with regard to the clonal plantation.

No information is available on the provenance of the

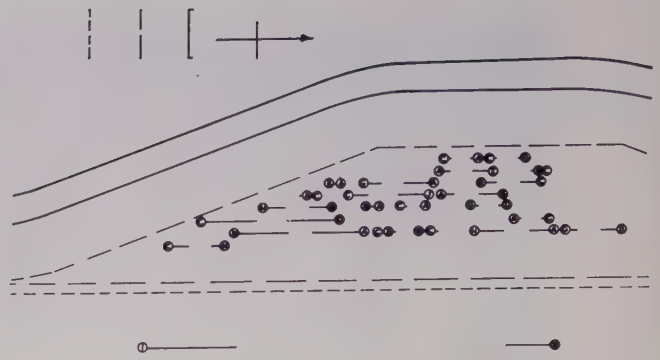

Fig. 5. Plan of the clonal plantation from which specimens were taken. Relative positions of the sampled trees, and the close proximity of the seedling trees are shown

two stands, but the characteristics of the trees suggest that they originate from one or both of the two northern provenances of *P. radiata* in California. The clones were sampled in October and November, 1959, and the seedlings in May, 1960. Table I gives the heights and breast-height diameters (d.b.h.) of the selected trees at the time of sampling.

Table I. Heights and Breast-Height Diameters of Selected Trees at Time of Sampling

	Height, ft.		*D.b.h., in.*	
	Mean	*S.E.*[a]	*Mean*	*S.E.*
Clones	40.6	±0.90	5.80	±0.231
Seedlings	46.7	±1.01	6.85	±0.269

[a] Sampling error.

The clones and seedlings were planted in the same year but whether they should be regarded as of the same physiological age with respect to wood characteristics is debatable. However, the macroscopic appearance of cross sections cleanly cut on both clone and seedling samples showed much the same characteristics. In some of the clones the growth rates of the two trees sampled were markedly different, but the same distinguishing features in matched rings could be readily detected (Fig 6).

Determination of Wood Characteristics

The following were carried out on green material from each specimen:

Ring Width. This was measured macroscopically for each growth ring along the north radius.

Percentage of Late Wood. The width of the late wood was measured in each ring, neglecting the obviously false rings.

Spiral Grain. The grain direction in the late wood of each growth ring was measured on a $^1/_4$-in. strip approximately $^7/_{16}$ in. wide taken from pith to bark on the north radius of each specimen. For comparison between trees, all results were adjusted with respect to zero reference for the outermost growth ring (*9*).

Longitudinal Shrinkage. This was determined on pieces 1 in. long and $^1/_4$ in. wide with the grain direction parallel to the 1-in. side, taken from late wood of successive growth rings in each specimen.

Incidence of Compression Wood. After determination of longitudinal shrinkage, longitudinal sections were cut and checked microscopically for compression wood.

Average Fiber Length. The last-formed late wood

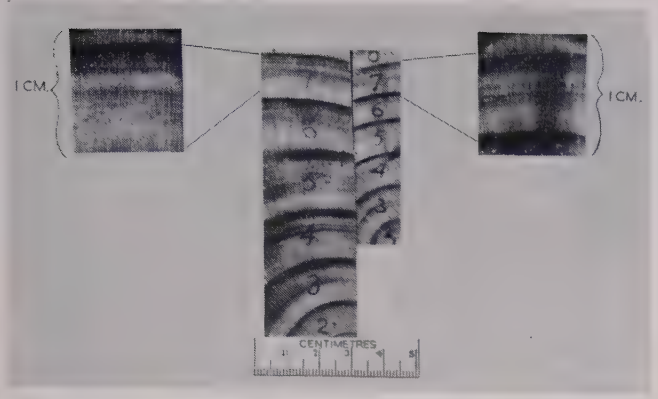

Fig. 6. Comparison of material from two trees of one clone. Ring features are very similar even though there is a markedly different growth rate between the two specimens

from each growth ring was macerated in a mixture of equal quantities of 100 volume hydrogen peroxide and glacial acetic acid by heating for 2 hr. at the temperature of a boiling water bath. Freed fibers were washed well and sampled. In each case approximately 50 *whole* fibers taken at random were measured using a projection microscope and a magnification of 40 diam.

Basic Density. This characteristic (the ratio of ovendry weight to green volume) was determined on all the wood of each growth ring in the case of whole ring basic density and on all the late wood of each ring in the case of late wood basic density.

Cellulose. This was determined on material representative of the 7th and 8th growth ring from the south radius using a semimicro modification of the method of Cross and Bevan (*22*).

EXPERIMENTAL RESULTS

The wood specimens taken from the various clones were examined by the methods outlined and the results of the various determinations tabulated according to growth-ring number from the pith. Care was taken to match growth rings; this was possible because of the marked similarity between particular rings of the different clones even though growth rates were dissimilar (see Fig. 6). Ring 1 was not used in the estimates because experience has shown that this ring often contains much compression wood. Results for growth rings 2 to 8 covering fiber length and basic density were averaged for the total number of trees in the test (44 trees from 22 clones) giving values of 2.69 mm. and 0.38 g./cc. (23.7 lb./cu. ft.), respectively. The extreme values were ± 14%, but the greatest between-tree variation within any one clone for these two properties was 9% of the averages for all trees. Figure 7 illustrates the marked similarity in results within a clone and at the same time indicates the marked variation possible between clones.

All results were submitted to statistical analysis to

Table II. Heritability of the Basic Density of *P. radiata* in the Australian Capital Territory

Age of plantation, yr.	*Annual rings used*	*No. of clones*	*Gross heritability*
20	Outer 9 rings	9	0.7
19	Rings 2 to 10	9	0.5
13	All rings from outside to pith	10	0.7

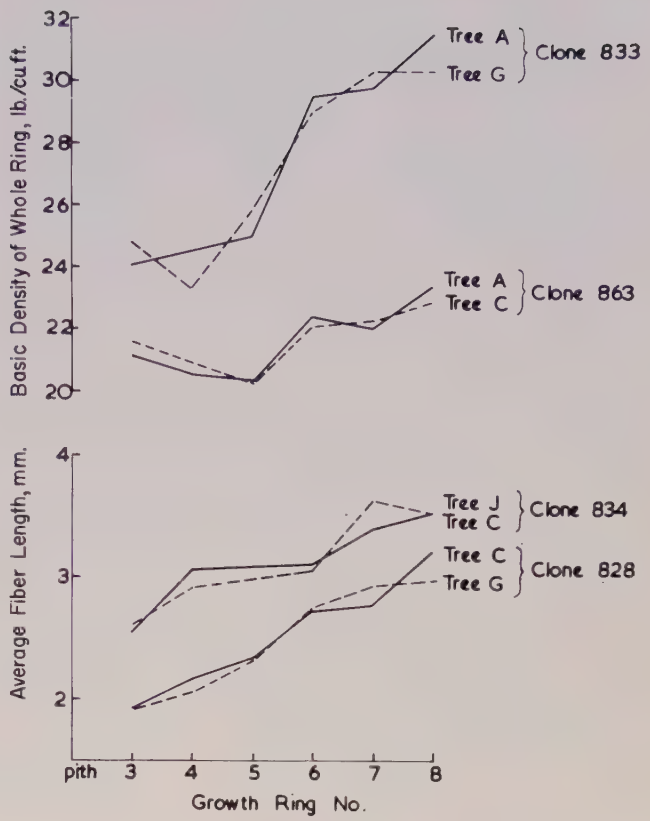

Fig. 7. Examples of within-clone and between-clone variations in **Pinus radiata** *from Australian Capital Territory*

separate the variation between trees into variation within clones and variation between clones. Heritability in its broad sense (or gross heritability), which may be defined as the proportion of the total variance of a characteristic which is due to hereditary differences among individuals, would then be estimated as follows:

$$\text{Gross heritability, \%} = \frac{\text{Between-clone variance}}{\text{Between-clone variance} + \text{Within-clone variance}} \times 100$$

Thus a feature with high gross heritability will show a high percentage; on the other hand, a low percentage will indicate that environmental factors are largely responsible for the variation observed. In the present examination an analysis of variance was carried out on the mean of the results for all growth rings from 2 to 8 inclusive of the clonal material. Separate analyses were made on results from growth rings 6, 7, and 8 only. The latter action was taken because other work on *P. radiata* specimens from larger trees in the same locality had indicated greatest within-tree variation in the first five growth rings from the pith (*23*). Also, in using a sample of uniform width and depth over a number of annual rings, the weight given to an individual ring (on a volume basis) increases greatly from the outside of the tree to the pith. The use of only three annual rings reduces the sampling error due to this effect.

Estimates of gross heritability based on rings 2 to 8 of the clones are set out in Table III. Table IV gives gross heritability figures for results on rings 6 to 8 inclusive, and Table V gives the between-clone correlations of certain of the features examined. These correlation coefficients, established by an analysis of

Table III. Gross Heritability Estimates Using Means of Growth Rings 2–8 Inclusive

Feature	*Based on specimens from clones, %*	*Based on specimens from seedlings, %*
Percentage late wood	54[a]	47
Basic density of whole ring	74[a]	57
Basic density of late wood	45[b]	N.E.[d]
Average fiber length	73[a]	83
Longitudinal shrinkage	54[a]	N.E.
Spiral grain	66[a]	N.E.
Ring width	21[c]	15

[a] Significant at 1% level.
[b] Significant at 5% level.
[c] Not significant.
[d] No estimate made.

covariance, measure the degree of association between the genetic components of the variation of these features.

A second estimate* of the gross heritability of ring width, percentage late wood, basic density and tracheid length of the whole ring for both rings 2 to 8 and rings 6 to 8 was made, by using the within-clone variances of these characteristics calculated from the clones, and their phenotypic variances calculated from the 29 seedling trees. Gross heritabilities were calculated from the equation:

$$\text{Gross heritability, \%} = \frac{\text{Variance of seedlings} - \text{Within-clone variance}}{\text{Variance of seedlings}} \times 100$$

The figures obtained for the features examined are also set out in Tables III and IV.

DISCUSSION OF RESULTS

These estimates of gross heritability must be considered in relation to the following:

The clones were not replicated in the plantation and so it is not possible to estimate the effects of the variation of the site. It is possible that any site variations that exist would tend to increase slightly the magnitude of the estimates: but the area covered by the clones is a small one, and appears to be relatively uniform. It is thus the opinion of the writers that any variation of the site itself has not influenced the estimates to an important extent.

The characteristics of the wood of *P. radiata* change greatly from annual ring to annual ring during its early life. Consequently, in considering heritability estimates, it is necessary to take into account the physiological age of the trees. Young clonal plantations are older physiologically than seedling plantations that have been established at the same time. Thus, the clones on which the estimates are based cannot be regarded as exactly the same physiological age as the seedling trees.

The estimates are to be regarded as preliminary in nature. They refer to *P. radiata* at the present stage of its breeding in the Australian Capital Territory, and to stands of the same physiological age growing on such sites as those in which the samplings were made. It is probable that the estimates based entirely on the clones more closely approximate the gross heritabilities prevailing in these stands than those based on both clones and seedling trees.

Fielding and Brown (*14*) estimated the heritability of the basic density of the wood of *P. radiata* in the Australian Capital Territory. Table II gives these estimates, based on borings at breast height.

In view of the small number of clones used in these estimates, the agreement between them and the estimates discussed in this paper (0.74 and 0.75) must be regarded as very satisfactory.

Restriction of consideration to the rings 6, 7, and 8 in the present investigation instead of rings 2 to 8 leads to some interesting results. While heritability figures for basic density and tracheid length are not greatly affected and, in fact, remain practically unchanged, those for spiral grain, and ring width, are markedly different. Spiral grain is generally more marked in the early growth rings and hence it is to be expected that genetic differences between the trees will be greater in these rings. Evidently, ring width in the early growth rings is strongly influenced by environmental factors, whereas when the trees have settled down to vigorous growth, the environmental factors have less effect. Percentage late wood, although apparently under a considerable degree of genetic control, has also been more affected by environment in the early years. Longitudinal shrinkage shows a somewhat similar trend; but here it is difficult to interpret the results because environment should not have any great influence except perhaps through cell length, which itself is mainly under genetic control.

The lack of genetic control on cellulose content is very interesting; but this result needs further investigation because most other workers have been convinced to the contrary.

The genetic correlations shown in Table V are also of interest, but as they are based only on this one clonal plantation (in which the clones are not replicated), they are to be accepted with some degree of reservation.

The correlation between ring width and basic density is of special significance because of the great importance of, and interest in, the relation between rate of growth and density. A phenotypic correlation between the ring width and basic density of rings 6, 7, and 8 was calculated for the 29 seedling trees. These trees,

* Suggested by F. Morley of the Division of Plant Industry of the C.S.I.R.O., Canberra. A method used by Toda (*1*).

Table IV. Gross Heritability Estimates Using Means of Growth Rings 6, 7, and 8

Feature	*Based on specimens from clones, %*	*Based on specimens from seedlings, %*
Percentage late wood	72[a]	45
Basic density of whole ring	75[a]	53
Basic density of late wood	54[a]	N.E.[d]
Average fiber length	81[a]	86
Longitudinal shrinkage	74[a]	N.E.
Spiral grain	28[b]	N.E.
Percentage cellulose	29[c]	N.E.
Ring width	63[a]	50

[a] Significant at 1% level.
[b] Not significant.
[c] Rings 7 and 8 only.
[d] No estimate made.

Table V. Genetic Correlations Based on Specimens from Clones

Percentage late wood/basic density of whole ring	0.62	Using means of rings 6, 7, and 8
Average fiber length/basic density of whole ring	0.45	
Ring width/basic density of whole ring	−0.66	
Average fiber length/percentage cellulose	0.51	Using means of rings 7 and 8
Basic density of whole ring/percentage cellulose	−0.04	

although sampled in order in a randomly selected row, are not a true random sample and the value of the correlation (−0.13), which is not significant, must be considered with this fact in mind. It is planned to obtain further information on this relationship in clonal and seedling tests.

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Some Anatomical Responses of Loblolly Pine to Soil-Water Deficiencies

DIANA M. SMITH and MARY C. WILSIE

Three 17-year-old loblolly pines from a good site at Crossett, Ark., were investigated at the midpoint of each annual height increment. A basipetal interaction was observed between the anatomical features studied and the June–October soil water deficits. Years of low water deficits were characterized by low percentages of summerwood at the apex and high percentages at the base of the corresponding increments; as water deficits increased this trend became less pronounced and in the year of severe drought it was actually reversed. The width of the summerwood zone, the radial counts and widths of the summerwood tracheids, and the specific gravity of the annual increments showed similar trends. The width of the annual increments at all heights in the trees, however, was negatively correlated with soil-water deficits such that the greater the deficit the narrower the ring.

This report covers part of a study undertaken by the Forest Products Laboratory in cooperation with the Crossett Research Center at Crossett, Ark., to determine the effect of summer soil-water deficits on the growth and structure of loblolly pine. Soil-water deficits occur quite commonly in the south as a result of high summer temperatures and low summer rainfall, and drought becomes one of the most significant factors limiting the growth of the southern pines (*16, 28*). The effects of drought, or water deficiency, are numerous and complex, since virtually all plant processes, such as transpiration, photosynthesis, assimilation, and respiration, are dependent in some manner upon the presence of water (*1, 5, 15*).

Diana M. Smith, Forest Products Technologist and Mary C. Wilsie, Forest Products Technologist, Forest Products Laboratory, maintained at Madison, Wis., in cooperation with the University of Wisconsin. Forest Service, U. S. Department of Agriculture.

It has been found that interruptions of normal growth processes resulting from drought are often expressed quantitatively in terms of reduced diameter growth and qualitatively in a low proportion of summerwood in the annual ring (*3, 6, 7, 12, 13, 14, 18, 22*). In these studies, soil-water deficits were estimated from records of seasonal rainfall only and the conclusions, while they hold generally, leave a sufficient number of conflicting results to merit closer investigation. Rainfall alone is not a good indication of soil-water deficits, since soil type, topography, and evapo-transpiration also strongly influence the available water supply. Furthermore, con-

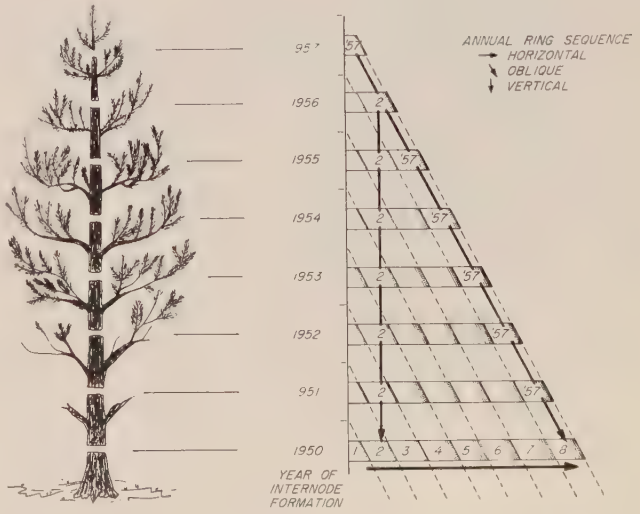


Fig. 1. Stem-analysis diagram of a young pine, illustrating the three annual ring sequences

clusions based primarily on increment cores or disks from one level in the sample trees do not take into account variations in summerwood amounts that are likely to occur higher in the same increment (*9, 21, 25*). Nor do they allow segregation of the environmental influences from the more basic patterns of growth.

Recent stem analyses of annual ring sequences along the horizontal, oblique, and vertical axes have brought into sharp focus the systematic nature of growth. In these analyses, the fundamental growth patterns are segregated from the random year-to-year fluctuations of the "wind and weather" type (*2, 11*).

Figure 1 represents a young pine tree in which the termination of each annual height increment is marked by a whorl of branches. Radial growth of the stem is by the successive addition of increment sheaths laid down by the cambium that could be considered as a nest of inverted cones. If sections are taken from the midpoint of each annual height increment, their appearance in a longitudinal radial section is illustrated in the diagram on the right of Fig. 1. The diagram is greatly simplified since, contrary to nature, each annual increment has been given the same width throughout its length in the tree. The arrows illustrate the three annual-ring sequences that express progressions in time and space within the tree (*2, 11*).

The horizontal sequence is the one most commonly used in growth studies. It traces the radial progression of annual rings from the pith to the bark in the same internode (illustrated in Figure 1 for the 1950 internode). Each annual ring from the pith outwards is produced by cambium of increasing age.

The oblique sequence traces the progression of a single year's growth as it passes from internode to internode down the tree (illustrated in Figure 1 for the 1957 increment). The progression of internodal cambia from which the increment is formed is also of increasing age.

The vertical sequence traces progression from internode to internode down the tree at a definite ring number from the pith (illustrated in Figure 1 for the second ring from the pith). These rings, making up the sequence, belong to different internodes and different years of growth, but they were produced by cambia having the same age.

It is possible, therefore, to pick up the age pattern in both the horizontal and the oblique sequences. The vertical sequence, on the other hand, is free from this age effect and shows very nicely the random year to year fluctuations of growth caused by changes in water supply and temperature. "Age" is used here to describe the developmental trend in the tree that has been attributed to a nutritive gradient in the cambium (*2*). This gradient is induced by the branch and foliage structure of the tree and is a species characteristic. Changes in stand density and related conditions can modify this pattern because they can affect the branching and rooting habits of the tree.

All three sequences were used in the analyses of the loblolly pine data presented here, but the one that provided the most information proved to be the oblique sequence. This sequence provided, also, explanations for the patterns of variation found in the other two sequences.

MATERIALS AND METHODS

The sample trees were three dominant 17-year-old loblolly pines from a fully stocked old-field stand at Crossett, Ark.* The soil under the stand was a well-drained silt loam with a site index of 90 to 95 (Height of trees in feet at age 50 years). Soil-water deficits were determined in this study from the difference between the potential and the actual evapo-transpiration for the site, that is, the difference between the water need and the water supply. They were calculated by personnel of the Crossett Research Center, and the raw data used for their determination were rainfall (recorded at the Center Headquarters, located about a mile from the research area) and the moisture-holding capacity of the soil (*27*).

The trees were cut in October, 1957,† and 1-in. thick disks were taken from breast height and from the midpoint of every annual-height increment above breast height. Each disk was measured using a microscope along the four cardinal radii and the following anatomical features were obtained for every annual ring from the pith to the bark: the annual ring width, the percentage of summerwood in the annual ring, the radial counts and dimensions of the tracheids in the springwood and summerwood zones, and for certain disks, the specific gravity—not only of the individual annual rings, but also of their separated springwood and summerwood portions. Mork's definition‡ of summerwood (*10, 20, 24*) was used throughout and specific gravity was determined by the maximum moisture method (*4, 19*).

RESULTS AND DISCUSSION

Water Deficits

Figure 2 shows the calculated soil-water deficits for the years 1943 through 1957. These are the totals for the period June through October since, for this area, water deficits were negligible prior to June (*26, 28*). The wettest year was 1950 with a deficit of less than an inch, and the driest year was 1952 with a deficit of over 15 inches. Other wet years were 1945, 1948, 1951, and 1957, and other drought years 1954 and 1956.

Annual Ring Width

Figure 3 shows a diagram of a longitudinal radial section through the three sample trees. It has been drawn to scale, and the average height of the sample trees is 52 ft. at 17 yr. of age and the average radius, inside bark at breast height is 3.5 in. The horizontal black lines represent the annual-height increments and the 1945, 1950, and 1955 internodes have been joined to indicate the variations in height growth among the three trees. The diagonal lines represent the annual increment sheaths and show the patterns of ring width for any one increment or for any height in the tree. Ignoring the shaded rings, it is apparent that ring width

* The sample trees were taken from the isolation strip surrounding the study area described by Dr. Robert Zahner in "Effect of Soil Moisture on the Diameter Growth and Summerwood Development of Loblolly Pine; Work Plan," Southern Forest Experiment Station, New Orleans, La., March 14, 1955.

† Although diameter growth was still in progress at the time of cutting, it was decided to include this increment in the analysis.

‡ All tracheids in which the common wall between two cell cavities multiplied by 2 is equal to or greater than the width of the lumen are considered as summerwood; those in which this value is less than the width of the lumen are considered as springwood (all measurements being made in the radial direction).

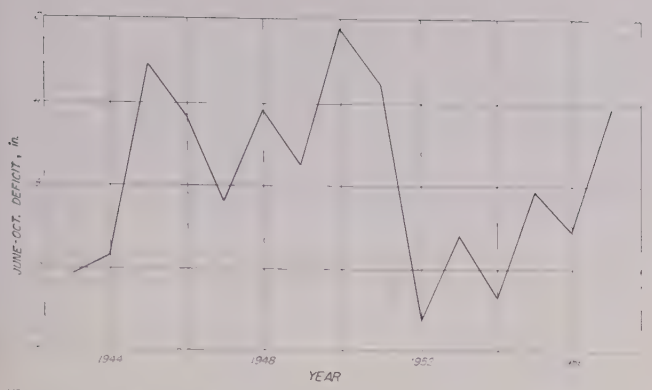


Fig. 2. Calculated soil-water deficits. June–October totals for 1943–1957 for a soil storing 14 in. of total available water at Crossett, Ark. Site index 90–95

becomes generally narrower from the pith outwards and from the apex downwards. This general pattern tends to obscure the very definite pattern of water deficiencies that is known to exist throughout the 14 or 15 yr. of growth shown here (Fig. 2). For instance, the 1950 increment is not easily picked up at all heights in the three trees (this was the year with practically no water deficit throughout the growing season), nor for that matter the 1952 increment (which was the severe drought year with a deficit of over 15 in.). Another pattern, which is not at first obvious, is that of maximum ring width in any one annual increment, shown by the shaded portion of the rings in Figure 3. The trend is for the point of maximum ring width to move downwards from the apex with each successive increment. For instance, in all three trees, ring width reaches a maximum at the second internode from the apex of the 1946 increment. For the 1951 increment, ring width reaches a maximum at the fourth internode from the apex, and for the 1956 increment, it reaches a maximum at the sixth internode from the apex in all three trees.

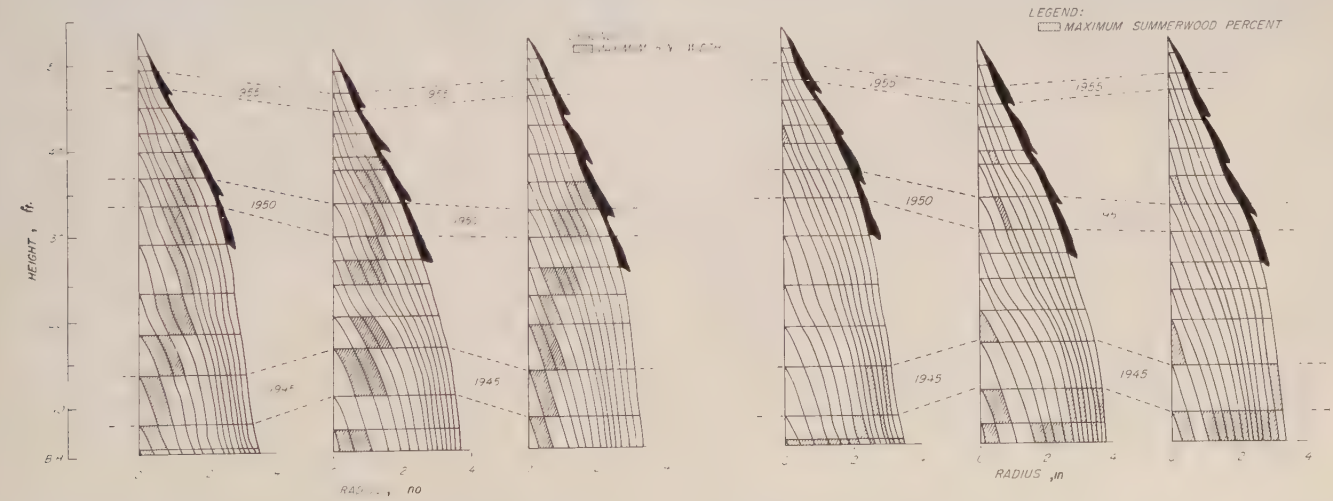
Since one of the purposes of the study was to determine the influence of soil-water deficit on ring width, examination of the vertical series will avoid these dominant patterns because in the vertical series, the rings are laid down by internodal cambia of the same age. A general agreement was found between ring width and the corresponding June-to-October water deficits (Fig. 14), such that the greater the deficit, the narrower the annual ring at all heights in the tree. The degree of correlation, however, was not high. This was to be expected, since growth started some time around March, and during this early growing period of March to June, there was never any lack of moisture.

Percentage of Summerwood in the Annual Ring

The influence of water deficits on the percentage of summerwood in the annual ring was more complex. Figure 4 shows the point of maximum summerwood percentage in the individual increment sheaths. For most of the increments, the point of maximum summerwood percentage is near the base of the trees and away from the tip. In general, the percentage of summerwood increases from the tip downwards, but there are certain notable exceptions. For instance, the percentage of summerwood reaches a maximum toward the tip of the 1952 increment in all three trees—this was in the severe drought year, and in tree no. 2, the percentage of summerwood reaches a maximum near the tip of the 1954 increment, in another drought year. Thus definite trends in summerwood development occur from the apex down through the successive internodes. These patterns of summerwood formation were studied and found to be satisfied by linear relationships.

Figure 5 shows the relationships between percentage of summerwood and internodes from apex for the wettest and the driest years (the 1950 and 1952 increments). The points indicate the experimental values, and the lines are the lines of best fit, calculated for the data by the method of least squares. The solid portion of the line indicates the range of the data. For the 1950 increment, summerwood percentage increased very rapidly from the apex downwards towards the base in all three trees, whereas for the 1952 increment, a negative relationship occurred, and summerwood percentage actually tended to decrease from the tip downwards.

Similar regressions were calculated for all the increments from 1945 (with 6 degrees of freedom) to 1957 (with 42 degrees of freedom) by combining the values for the three trees. The results are shown in Fig. 6.



Figs. 3 and 4. Diagram of the three sample trees

The shaded portion is the point of maximum ring width in the annual increment sheath.

The shaded portion is the point of maximum percentage of summerwood in the annual increment sheath.

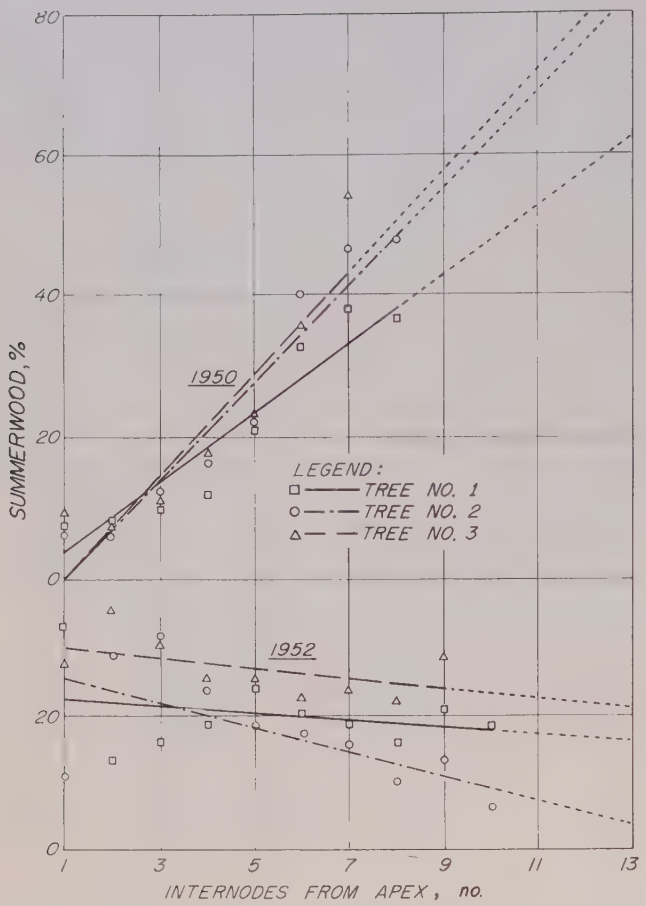


Fig. 5. The relationship between percentage of summerwood and internodes from apex for the three sample trees in 1950 and 1952 oblique series, site index 90–95

The solid lines indicate the range of the data, and the broken lines designate their projections. The lines with the steeper slopes represent the wetter years (1950, 1945, 1957), and the lines with the lesser slopes, the drought years, which may even have a negative slope, such as the 1952 increment. The point of intersection of these lines lies within about the first seven internodes from the apex which, because of the symmetry of tree growth, is also the first seven rings from the pith—commonly considered the juvenile zone (*8*, *29*).

The slopes of these lines were plotted against year of

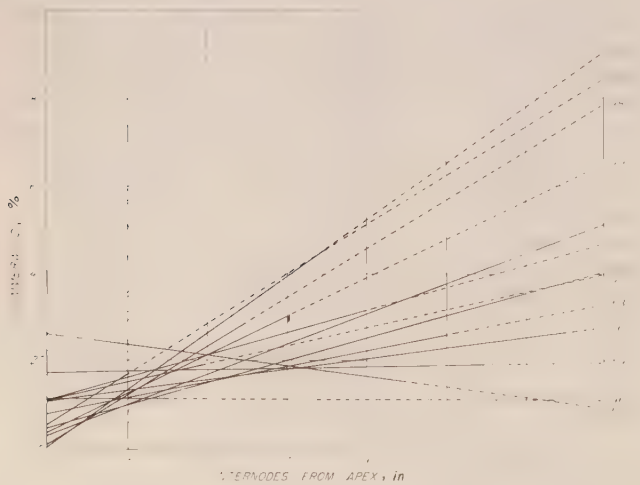


Fig. 6. The relationship between percentage of summerwood and internodes from apex for the 1945–1957 increments. Oblique series, site index 90–95, av. of three trees

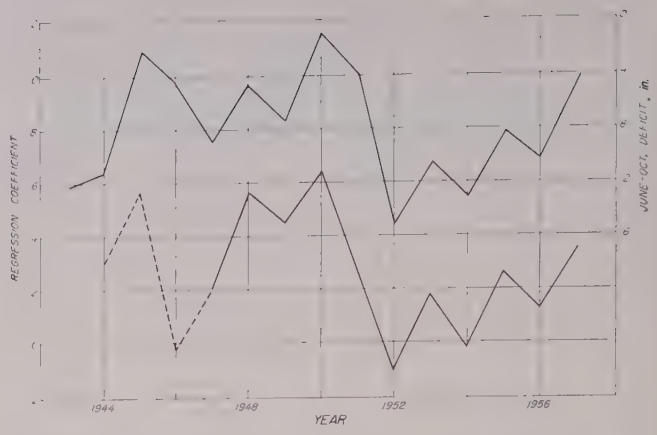


Fig. 7. Upper curve, soil-water deficits. Lower curve, regression coefficients for percentage of summerwood on internodes from apex (calculated for the three trees combined). Oblique series, site index 90–95

The dotted portion represents regression coefficients with 12 or less degrees of freedom.

formation (Figs. 7 and 11). The upper curve is the water-deficit curve and the lower curve represents the regression coefficients for summerwood percentage on internodes from apex. The dotted portion of the curve indicates a range in the degrees of freedom from only 3 to 12. Except for the 1946 increment, there is a very close relationship between summerwood formation and summer water deficits and, moreover, the variability between trees is small (Fig. 8). When the curves are caluclated for the individual trees, the degrees of freedom are considerably reduced, but where the degrees of freedom are relatively high—up to 13 in 1957—the agreement is almost perfect. Yet, even where the degrees of freedom vary from 3 to 6 (1947–1950), the pattern of water deficit is clearly evident.

Other Structural Features

Very similar relationships were found between regression coefficients and water deficits for the other structural features studied, such as the width of the summerwood zone (Fig. 9), the radial count of the tracheids in the summerwood zone (Fig. 10), the average radial width of the summerwood tracheids (Fig. 12), and the specific gravity of the annual ring increments (Fig. 13). In the case of cell size (Fig. 12), the relationship between cell diameter and internodes from apex is

Fig. 8. Upper curve, soil-water deficits. Lower curve, regression coefficients for percentage of summerwood on internodes from apex for each of the three sample trees. Oblique series, site index 90–95

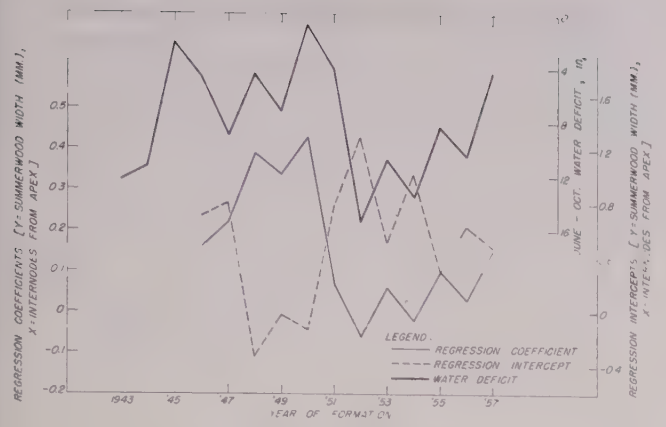

REGRESSION COEFFICIENTS (Y = SUMMERWOOD WIDTH (MM.), X = INTERNODES FROM APEX)
JUNE - OCT. WATER DEFICIT, IN.
REGRESSION INTERCEPTS (Y = SUMMERWOOD WIDTH (MM.), X = INTERNODES FROM APEX)
LEGEND:
REGRESSION COEFFICIENT
REGRESSION INTERCEPT
WATER DEFICIT
YEAR OF FORMATION

Fig. 9. Soil-water deficits, regression intercepts, and regression coefficients for the relationship between the radial width of the summerwood zone and internodes from apex. Oblique series, site index 90–95

Regressions are calculated for the three sample trees combined.

actually curvilinear, so that a log-log transformation of the data was made to obtain a linear relationship. For all the other structural features shown, the relationships were linear.

When there is virtually no water deficit, such as in 1950, the width of the summerwood zone in the annual ring increases by 0.4 mm. (Fig. 9) with every internode from the tip downwards; the number of tracheids in the summerwood zone increases by 15 in the radial direction (Fig. 10); the percentage of summerwood in the annual ring increases by 6% (Fig. 11); and the specific gravity increases by only 0.03 (Fig. 13) for each internode from the apex downwards. Cell diameter (Fig. 12) is not so easily interpreted as it is in the log-log form. During a severe drought year, such as 1952, the width of the summerwood zone may actually decrease by 0.07 mm. (Fig. 9) for each internode down the tree; the number of tracheids in the summerwood zone may decrease by three (Fig. 10); the percentage of summerwood may decrease by $1^1/_2$% (Fig. 11); and specific gravity increase by only 0.005 (Fig. 13) for each successive internode from the tip downwards.

Table I

Wood property	*Annual increment* Tip	Breast height
Width of summerwood zone, mm.		
Water deficit negligible	0.30	4.59
Severe drought	1.23	0.60
Summerwood tracheid count in the radial direction, number		
Water deficit negligible	27.8	167.0
Severe drought	59.0	29.3
Amount of summerwood in the annual ring, %		
Water deficit negligible	1.2	64.0
Severe drought	26.0	14.4
Annual ring specific gravity		
Water deficit negligible	0.309	0.595
Severe drought	0.364	0.399

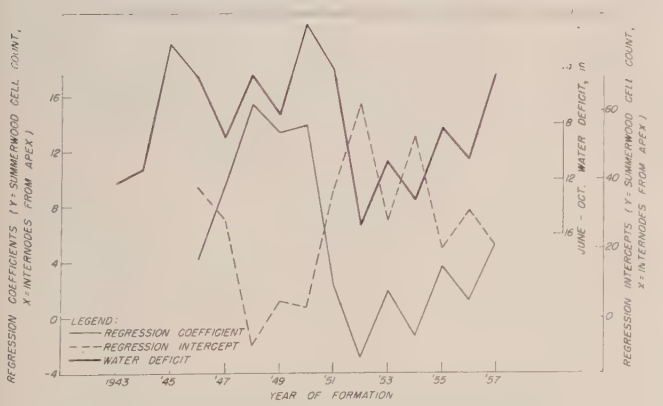

REGRESSION COEFFICIENTS (Y = SUMMERWOOD CELL COUNT, X = INTERNODES FROM APEX)
JUNE - OCT. WATER DEFICIT, IN.
REGRESSION INTERCEPTS (Y = SUMMERWOOD CELL COUNT, X = INTERNODES FROM APEX)
LEGEND:
REGRESSION COEFFICIENT
REGRESSION INTERCEPT
WATER DEFICIT
YEAR OF FORMATION

Fig. 10. Soil-water deficits, regression intercepts, and regression coefficients for the relationship between the number of tracheids in the summerwood zone and internodes from apex. Oblique series, site index 90–95

Regressions are calculated for the three sample trees combined.

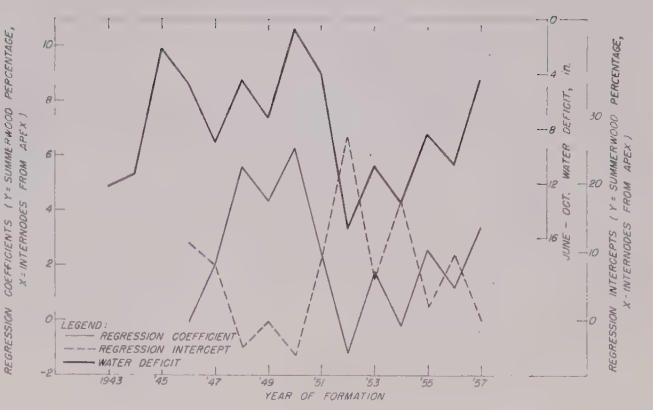

REGRESSION COEFFICIENTS (Y = SUMMERWOOD PERCENTAGE, X = INTERNODES FROM APEX)
JUNE - OCT. WATER DEFICIT, IN.
REGRESSION INTERCEPTS (Y = SUMMERWOOD PERCENTAGE, X = INTERNODES FROM APEX)
LEGEND:
REGRESSION COEFFICIENT
REGRESSION INTERCEPT
WATER DEFICIT
YEAR OF FORMATION

Fig. 11. Soil-water deficits, regression intercepts, and regression coefficients for the relationship between percentage of summerwood and internodes from apex. Oblique series, site index 90–95

Regressions are calculated for the three sample trees combined.

In Figures 9 to 13, not only are the regression coefficients shown (the solid lines), but also the regression intercepts (the broken lines). From this information, it is possible to calculate the variation in structural features that can be attributed to soil-water deficits in a loblolly pine with a ring count of 10 at breast height—these are summarized in Table I.

Importance of Analytical Method

So far, the emphasis has been on the oblique series, or the effect of position in the tree upon certain anatomical features during a given set of environmental conditions. It has been demonstrated that there is a close correlation between these features and soil-water deficits. Had the study been confined to either

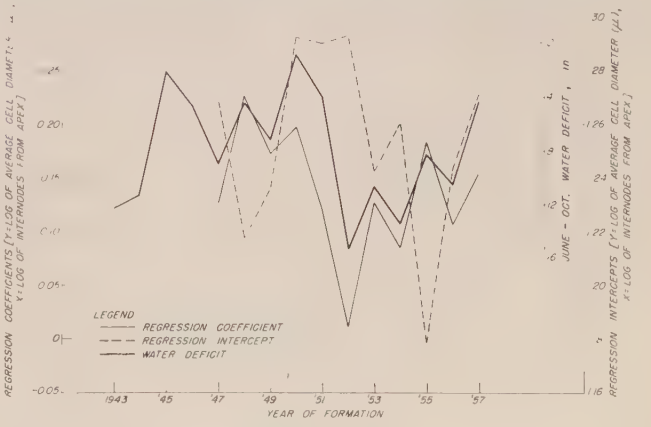

REGRESSION COEFFICIENTS (Y = LOG OF AVERAGE CELL DIAMETER, X = LOG OF INTERNODES FROM APEX)
JUNE - OCT. WATER DEFICIT, IN.
REGRESSION INTERCEPTS (Y = LOG OF AVERAGE CELL DIAMETER (μ), X = LOG OF INTERNODES FROM APEX)
LEGEND
REGRESSION COEFFICIENT
REGRESSION INTERCEPT
WATER DEFICIT
YEAR OF FORMATION

Fig. 12. Soil-water deficits, regression intercepts, and regression coefficients for the relationship between average radial diameter of the summerwood tracheids and internodes from apex. Oblique series, site index 90–95

Regressions are calculated for the three sample trees combined.

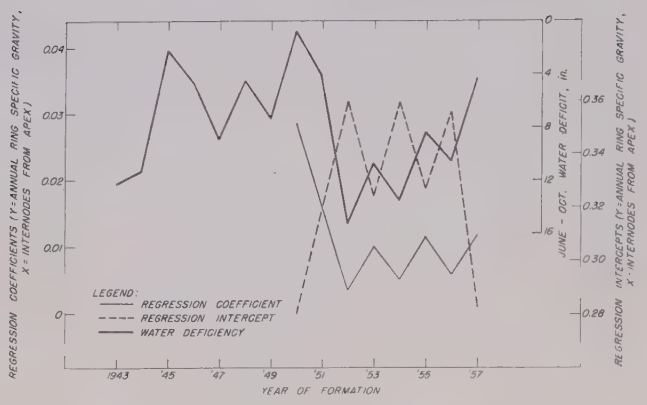

REGRESSION COEFFICIENTS (Y=ANNUAL RING SPECIFIC GRAVITY, X=INTERNODES FROM APEX)
JUNE - OCT. WATER DEFICIT, in.
REGRESSION INTERCEPTS (Y=ANNUAL RING SPECIFIC GRAVITY, X=INTERNODES FROM APEX)
LEGEND:
REGRESSION COEFFICIENT
REGRESSION INTERCEPT
WATER DEFICIENCY
YEAR OF FORMATION

Fig. 13. Soil-water deficits, regression intercepts, and regression coefficients for the relationship between annual ring specific gravity and internodes from apex. Oblique series, site index 90–95

Regressions were calculated for the three sample trees combined. Specific gravity determinations were made for only 10 internodes (namely, breast height, 1946, and 1950–1957), and the degrees of freedom reduced correspondingly.

the vertical or the horizontal series, no such definite relationships would have been found.

As an example, the patterns of variation in percentage of summerwood according to the vertical and the horizontal series are illustrated in Fig. 15. In the vertical series, each member is the product of cambia of uniform age. The longest curve represents the variation in percentage of summerwood for the first annual ring from the pith, from the base of the tree (where it was laid down in 1943) to the tip (where it was laid down in 1957). Each succeeding ring from the pith was plotted so that years of formation coincide. In the horizontal series, each member represents the radial variation in percentage of summerwood from the pith to the bark in the same internode. The longest curve represents breast height, and all succeeding heights are plotted so that years of formation coincide, i.e., lining them up on the bark side with calendar years coinciding. For both series, the broken lines indicate the first seven rings from the pith and the solid lines represent remaining rings.

The relationship between water deficit and summer-

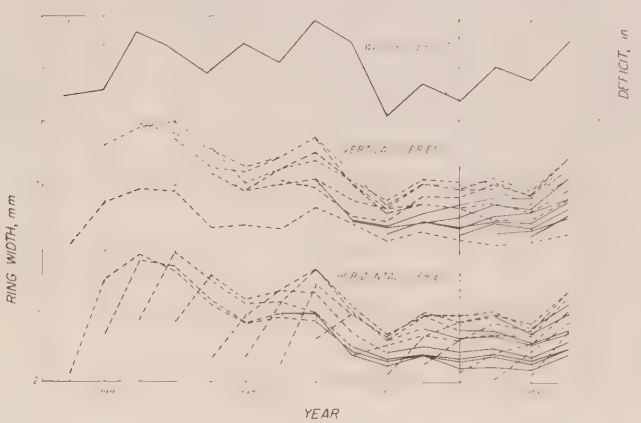


Fig. 14. Variations in ring width for the vertical and horizontal series, including the soil-water deficits for the corresponding years. Site index 90–95, av. of three trees

The broken lines represent the first seven rings from pith and the solid lines indicate the remaining rings.

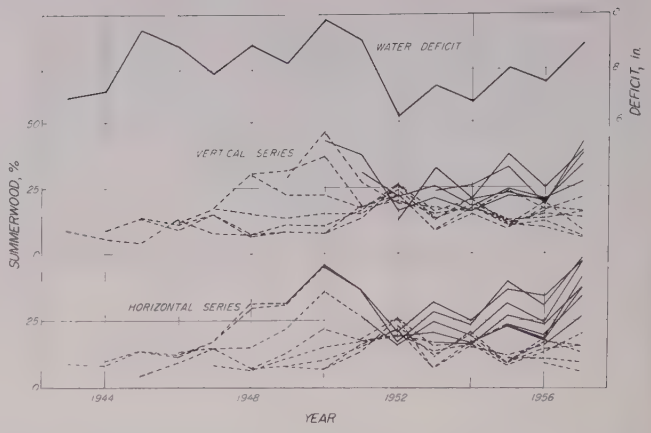


Fig. 15. Variation in percentage of summerwood for the vertical and the horizontal series, including the soil-water deficits for the corresponding years. Site index 90–95, av. of three trees

The broken lines represent the first seven rings from pith and the solid lines indicate the remaining rings.

wood percentage in both series is generally positive in the juvenile wood and negative in the adult wood. This relationship, however, is by no means clearly defined and any inferences that could be made would have to be inconclusive. The oblique series, however, shows a very definite and consistent correlation, and the apparent contradictions between juvenile and adult wood in both the vertical and the horizontal series can be explained by the intersection of the regressions of the oblique series (Fig. 6). The patterns of variation in radial diameter of the summerwood tracheids, shown in Fig. 16, can be similarly explained.

Physiological Interpretations

These results apply to young and vigorously growing trees only. If predictions were made for older trees on the basis of these data, the values would soon become absurd, as can be seen from Fig. 6. Here, further projection of the regression lines would yield negative values for the drought year, 1952, and values in excess of 100% for the 1950 increment. There is

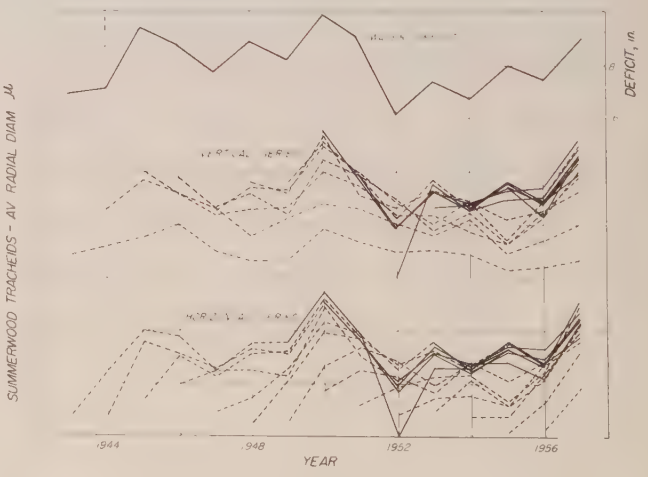


Fig. 16. Variation in average radial diameter of the summerwood tracheids for the vertical and the horizontal series, including the soil-water deficits for the corresponding years. Site index 90–95, av. of three trees

The broken lines represent the first seven rings from pith and the solid lines indicate the remaining rings.

evidence, however, to indicate a decreasing response to environmental conditions as a result of decreasing vigor of growth or increasing age of the trees (*7, 17*).* Therefore, further studies are needed to extend these investigations to include older age classes and other species.

Certain structural trends occurring basipetally in the annual increment of young loblolly pine were observed and described, but no attempt has been made to discuss the nature of the physiological process that might give rise to the observed trends. The hormone theory of cambial activity provides a clue; this theory is reviewed elsewhere (*5, 12, 23*) and has been summarized as follows: "... auxin produced in the young, growing leaves and expanding buds is transmitted down the stem and stimulates division in the cambium. The long-established connection between the presence of expanding buds and cambial activity is thereby explained. So also is the well-known observation that the cambial stimulus is transported in a basipetal direction only, for it is a characteristic of auxin that it normally moves only in this direction (*23*)." This author suggests that while young leaves are much richer in auxin than mature leaves, the small amounts of auxin produced in the latter may be sufficient to account for the continued production of summerwood after extension growth has stopped. He goes on to say, "It seems probable that the difference between springwood and summerwood is ultimately due to a difference in the level of auxin reaching the cambium." This conclusion would seem to be applicable to the results presented here and it is possible that the negative trend in summerwood formation from the apex downwards, observed in the year of severe drought, was the result of restricted translocation of the photosynthates and auxins caused by severe internal water deficits.

SUMMARY

In a study of three dominant 17-year-old loblolly pines from a site index of 90 to 95 at Crossett, Ark., a close correlation was found between certain anatomical features and the June–Octobers oil-water deficits. The correlation between ring width and soil-water deficits for the corresponding years was negative at all heights in the trees, such that the greater the water deficit, the narrower the ring. The influence of water deficit on the other features studied, such as the width of the summerwood zone, the radial counts and dimensions† of the summerwood tracheids, the percentage of summerwood in the annual ring and its specific gravity, was more complex.

These structural features exhibited a basipetal interaction with June–October soil-water deficit in the following way: an annual increment produced during a year of low water deficit is characterized by a low percentage of summerwood at the apex of the increment and a high percentage of summerwood at the base of the increment, whereas in years of greater water deficits, the trend becomes less pronounced. In fact, in a severe drought year, this relationship may even be reversed, so that the percentage of summerwood is actually higher at the apex of the increment than it is at the base. The width of the summerwood zone and the radial count of the tracheids in the summerwood zone responded in a similar manner to soil-water deficits, as did the radial diameter of the summerwood tracheids when transformed to log-log in order to obtain a linear relationship. The specific gravity of the annual increments also followed the same trend, except that even under severe drought conditions, the relationship did not become negative.

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* In February 1960, a 35-year-old loblolly pine was obtained from within 100 yards of the trees used in this study. Preliminary investigations of the percentage of summerwood in the 1943–1957 increments measured at the midpoint of every internode, gave a similar pattern; the magnitude of the regression coefficients, however, was only about one-third of that obtained for the younger trees.

† The conclusion that available soil moisture influences cell diameter confirms earlier findings based on seedlings of loblolly pine (*22*).

Some Effects of Fertilizers on Wood Properties of Loblolly Pine

B. J. ZOBEL, J. F. GOGGANS, T. E. MAKI, and F. HENSON

A study was made of the effects of a high level and moderate level of fertilization on the wood of loblolly pine. The trees are presently 25 years old and the first of three consecutive annual fertilizer applications was applied when the trees were 16 years old. The wood analyzed and compared was that formed the 7 years prior to and the 7 years following the first fertilization. Results indicated that (1) heavy rates of fertilization resulted in wood of considerably lower specific gravity; (2) fertilizers caused a trend for shorter tracheid lengths but the differences were not statistically significant; (3) a similar trend of lower alpha-cellulose and water-resistant carbohydrates (holocellulose) was also evident, but again the results were not statistically significant; (4) an increase in diameter growth was evident but, as for (2) and (3) above, was not statistically significant.

WITHIN the past decade a tremendous interest has been generated in the possibility of fertilizing forest stands. Much fertilizer actually has been spread in the woods, both in demonstrations and in designed experiments. In all this activity, the major emphasis has been on volume growth, frequently and unquestionably heightened by expectations of some dramatic increase in rate or nature of response. With few exceptions, practically nothing has been said, or implied, about the possible effects of fertilizers either on wood quality *per se*, or on specific properties associated with it. Yet it must be admitted that any beneficial effects on wood properties from fertilizing would augment any resulting volume increases: and conversely, any deleterious effects would as surely tend to reduce or cancel them.

The implications of the interrelationships between fertilizing and wood quality seem quite clear. Take, for example, tree improvement work in the southern pine region. Currently, one major emphasis in this work is being placed on desirable wood properties. If, in breeding new strains, it is desired to combine the use of fertilizers with the newly developed trees, it seems relevant to find out whether fertilizers significantly modify those wood properties regarded as desirable. Such information would be all the more necessary, if forest fertilization becomes an accepted practice for stimulating volume increment.

This paper presents some preliminary evidence that certain levels of NPK (nitrogen, phosphorous, and potassium) fertilizers significantly alter wood properties, especially specific gravity. Studies were made on planted loblolly pine (*Pinus taeda*) that averaged 36 ft. in height and 5.2 in. in diameter (breast high) when the first of three consecutive annual applications of fertilizers was made.

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This exploratory phase on wood properties is a part of a larger study on forest fertilization undertaken in 1951 by the North Carolina State College School of Forestry in cooperation with the Nitrogen Division of the Allied Chemical Corp. The authors are indebted to Drs. R. J. Preston and C. M. Kaufman under whose direction the original study was initiated, and to Dwight L. Brenneman who installed the plots.

PREVIOUS RESEARCH

Forestry literature contains only a very limited amount of information dealing directly with the effects of fertilizer on wood properties. Erickson and Lambert (*1*) analyzed the effects of fertilizer on 30-year-old Douglas-fir (*Pseudotsuga menziesii*) from plots, some of which had also been subjected to thinning. Their samples were taken from four trees per plot, the wood analyzed being that laid down four years prior to and four years following the fertilization and thinning treatments. Their results indicate that the combined effects of these treatments significantly decreased specific gravity and also caused a slight drop in holo- and alpha-cellulose yields. Wilde and Voigt (*2*) showed that jack pine (*P. banksiana*) seedlings grown in coarse, sandy, unfertilized soil had an average specific gravity of 0.41, but when grown under heavily fertilized conditions, their average specific gravity dropped to 0.23.

The influence of potassium fertilizer on planted red pine (*P. resinosa*) was studied by Heiberg, *et al.* (*3*), on marginal sites where a deficiency of this element was suspected. Volume and dry matter both went up with increased fertilizer levels, and the increases were independent of plantation spacing. Wardrop (*4*), showed that *P. pinaster*, which had been very slow-growing but responded well to superphosphate, had a drastic reduction in tracheid length following fertilization. Tracheid length rapidly returned to normal a few years following fertilization.

Paul and Marts (*5*) found that for longleaf pine (*P. palustris*), in natural stands on deep Florida sands, combined fertilization and irrigation increased both springwood and summerwood. Summerwood increase was greater, however, thus probably resulting in an overall higher specific gravity. A complete fertilizer without irrigation increased springwood but decreased summerwood in their seven-tree sample, thus suggesting that this treatment actually decreased specific gravity. Application of nitrogen alone increased both spring- and summerwood, but again the increase in the latter was more pronounced. It appears likely then, that in longleaf pine, certain fertilizers alone or in combination with irrigation may bring about some increase in specific gravity: Paul and Marts (*5*) made no report of this.

Tsuda (*6*) found that the airdry weight of Japanese larch seedlings was essentially unaffected by changes in potassium levels. Uchida, *et al.* (*7*), found that overall green weights of seedlings grown under certain fertilizer regimens were greater than those grown under

other regimens, and that green weights of roots increased with higher phosphorus levels in the soil. It is not known whether the observed weight increases were due mainly to greater wood substance or to something else. In reporting on the effects of fertilizer treatments on forest trees, Pechman (*8*) found that (N) fertilization of slow-growing pine increased both ring width and late-wood (summerwood) per cent but (N) fertilization of spruce stimulated chiefly the early-wood (springwood) growth.

Although many studies have dealt with differences in wood properties of trees grown under different native soil–site conditions, the results are far from being in agreement. In some instances, lower specific gravities have been reported for wood from good sites; in others, opposite results have been found. In many such studies, differences in soil moisture, microclimate, and stand density are badly confounded, making any clear separation of nutrient-level effects difficult or impossible. Although a review of the interactions and interrelationships of wood properties and site quality would be interesting, such a task is beyond the scope and the space allotted to this paper. Similarly, a large body of literature is available on the effects of fertilizer on volume growth rate *per se;* much of this literature is also contradictory. The present paper does not attempt a critical assessment of fertilizer effects on volume growth rates, but some incidental data on growth will be presented.

Several workers have suggested the possibility that individual trees within a species may react differently when fertilized because pine has evolved on soils of low native fertility. The general concept of differential reaction to fertilizers has been discussed by York (*9*). There is always the possibility that certain strains, or individual trees, may behave differently under different environmental conditions, and raising the fertility level of a poor site by application of fertilizers to the equivalent native level of a better site may well fail to result in a comparable growth response (*10*). Such differential responses could extend not only to volume-growth characteristics but also to the quality of wood produced. Care must be taken in interpreting effects where a naturally adapted type is treated and results in a drastically changed site. For example, if naturally drought-hardy seedlings are watered, the resultant changes cannot be extrapolated to say what conditions would be if nondrought-hardy seedlings were grown on a moist site: this shows only what the conditions would be on a moist site if drought-hardy trees were planted there. It does not indicate how inherently "moist site individuals" would react under these same conditions.

RESEARCH METHODS

The sample trees in this study are growing in a loblolly pine plantation, established in 1935 on Georgeville clay loam (a typical red Piedmont soil) and situated on the Hill Forest in Durham County, N. C. Initial plantation spacing was approximately 6 by 7 ft. Experimental fertilizer treatments were applied to replicated plots in this plantation in March, 1951; the treatments being various combinations and levels of nitrogen, phosphorus, and potassium. Applications were repeated in March 1952, and March 1953, with identical combinations, levels, and carriers. The overall individual plot size is 37 by 84 ft. The original 13 treatments were replicated twice and were designed to assess fertilizer effects on diameter and height growth, on rate of natural pruning and expression of dominance, on vigor and foliage composition, and on other characteristics that may be observed. Nitrogen was applied as ammonium nitrate in quantities of 80 and 160 lb. N per acre. Phosphorus as treble super phosphate and potassium as potassium nitrate were applied at rates of 40 and 80 lb. per acre of P_2O_5 and K_2O respectively. Other details of establishment, plot history, and initial observations are given by Brenneman (*11*).

Although this study was not established initially for the purpose of determining fertilizer effects on wood properties, it was recognized that, given sufficient time, such determinations could be made. Thus, after eight growing seasons had elapsed since the first of the three annual, consecutive fertilizer doses had been applied, it was decided to make an evaluation of wood samples from some of the treatments to determine to what extent, if any, fertilization had altered or modified certain wood properties.

For this preliminary study, only three fertilizer treatments were selected from the 13 that had been installed in 1951. These three treatments were: (1) no fertilizer, i.e., the check plots; (2) 80-40-40 lb. per acre of N, P_2O_5, and K_2O, respectively; and (3) 160-80-80 lb. per acre of the same constituents as in (2). Approximately 12 trees per treatment were sampled in each of the two random plots; so each treatment is represented in this study by approximately 24 trees. In no plot were there less than nine trees sampled.

Two large-diameter (11 mm.) increment cores were extracted at 180° to each other from the sample tree at the breast-high position, i.e., 4.5 ft. above general ground level. Cores with visible pitch deposits, knots, compression wood, or other defects were rejected and replaced by clean cores from the same trees in which such defects were encountered. Sampling was confined to dominant and codominant trees.

Each core was tested in the laboratory for compression wood and hidden pitch pockets by means of the light box, a device developed by the Forest Products Laboratory (*12*). Cores passing this test of acceptance were then divided into two parts: (1) the seven years prior to the first application of fertilizer, and (2) the seven years following the first (March, 1951) application. Specific gravity and tracheid length were determined for both segments of each core, thus amounting to four determinations of each of these properties for each sample tree. In a few instances the prior-fertilization segment of the core had to be reduced from 7 annual rings to 6 rings in order to avoid inclusion of juvenile or corewood in the sample. As pointed out by Zobel, *et al.* (*13*), this separation obviates much of the confusion of some past wood-property studies which have ignored the presence of corewood in the samples.

Specific gravity was obtained by the standard method of determining ratio of green volume to dry weight, wood volume being obtained by displacement of water.

Tracheid lengths were determined by a Rayoscope microscope projector using a magnification of 26×. Summerwood from the middle ring of each seven-ring segment was macerated by the chromic–nitric acid method, and all tracheid lengths reported are from

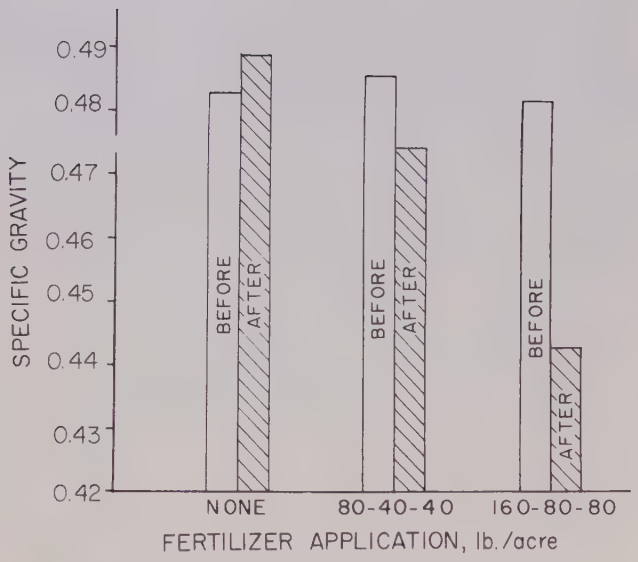

Fig. 1. Graphical representation showing the effects of fertilizers on wood specific gravity

these two growth rings. Tracheids were stained with basic fuchsin. Mounting of this macerated material on slides was accomplished with sodium silicate. Three slides were made for each wood sample and a total of 40 undamaged tracheids were measured from them. If three slides failed to provide 40 intact tracheids, additional slides were prepared until the requisite number were measured. Extreme care was exercised to avoid measuring tracheids with broken ends. It has been observed that many tracheids which appear normal and intact under standard magnifications actually are found with broken ends when viewed and inspected critically under the higher magnifications of the Rayoscope.

In contrast to specific gravity and tracheid length determinations, only two determinations per tree were possible for alpha-cellulose and water-resistant carbohydrates (WRC)[1] analysis, since the two corresponding core segments from each tree had to be combined to provide enough wood material for analysis. The cellulose determinations were made by the rapid method of Yundt and Bradway (*see* Zobel and McElwee (*14*)).

[1] Similar to holocellulose.

RESULTS

Specific Gravity

Figure 1 and Table I show that three consecutive annual applications of NPK fertilizers significantly reduced the specific gravity of loblolly pine. Reduction was much greater for the heavier fertilizer application, and specific gravity averaged 10% less than in trees in the control plots. It is pertinent to note that the "before" segments of the control samples differed but slightly from the "after" segments, being a little higher for the latter period, as might be expected because of their greater age. This slight difference, nevertheless, indicates that the effort to separate the lower-specific-gravity core wood from the wood samples was quite successful.

The reduction in specific gravity as a result of the heavier fertilization, based on estimates supplied by Taras (*15*), amounts to about 330 lb. in green weight per cord. The moderate fertilizer treatment produced a green weight loss of about 100 lb. per cord, in contrast to unfertilized (check) trees which gained an average of about 50 lb. per cord in the same period.

The genuineness of the fertilizer-treatment effects was verified by analyses of variance, which showed also that individual trees differed significantly from one another. Wood from moderately fertilized trees was lower in specific gravity than wood from nonfertilized trees, the difference being significant at the 5% level. Similarly, the specific gravity of wood from heavily fertilized trees was lower than that from moderately fertilized trees at the 5% level, and from the control trees at the 1% level.

Since the numbers of codominant and dominant sample trees differed by plots, being 9 and 10 for heavy fertilized replications, 11 and 12 for moderate fertilization, and 13 and 11 for control plots, a test was made to determine whether these differences affected the results of the analysis of variance. No influence was discovered.

A further point of interest was the possibility that trees with markedly different specific gravity values might react or respond differently to fertilizers. Accordingly, correlation coefficients r between specific gravity *before* fertilizing and change *after* fertilizing were computed for each treatment. The resulting coefficients were low and not significant for heavy fertiliza-

Table I. Properties of Wood Before and After Fertilization in Planted Loblolly Pine, 25 Years Old at Time of Sampling, 19 to 24 Trees per Treatment

Rate of fertilization per sample plot

	Heavy (160-80-80)		*Moderate (80-40-40)*		*None (check)*		*Av.—All*	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
				Specific Gravity[a]				
Before fertilization	0.479	0.44–0.55	0.486	0.43–0.54	0.484	0.41–0.54	0.483	0.41–0.55
After fertilization	0.442	0.40–0.54	0.475	0.44–0.51	0.489	0.42–0.55	0.469	0.40–0.55
				Tracheid Length, mm.[b]				
Before fertilization	3.47	2.9–4.3	3.44	2.9–3.9	3.53	2.9–4.2	3.48	2.9–4.3
After fertilization	3.72	3.4–4.4	3.80	3.4–4.3	4.08	3.3–4.7	3.87	3.3–4.7
				Water Resistant Carbohydrates, %[c]				
Before fertilization	80.3	79–82	80.5	79–82	80.3	79–81	80.4	79–82
After fertilization	80.5	80–82	80.6	79–82	80.7	79–82	80.6	79–82
				Alpha-Cellulose, %[c]				
Before fertilization	54.4	52–56	55.1	53–57	54.4	52–56	54.6	52–57
After fertilization	53.6	52–56	54.9	52–57	55.0	53–58	54.5	52–58

[a] Average of two plots, based on two determinations per tree, opposite sides of tree, at 4.5 ft.
[b] Based on total of 80 (40 from each of two sides of tree) tracheid measurements each before and after fertilization, per tree, at 4.5 ft.
[c] Based on two determinations of one composite sample from both sides of tree, before and after fertilization, at 4.5 ft.

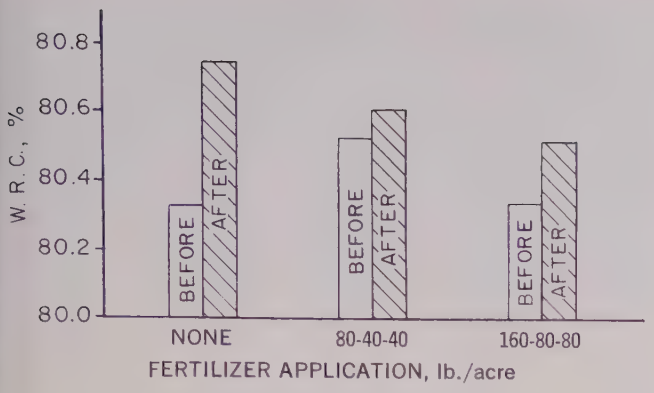

Fig. 2. Effect of fertilizer on water-resistant carbohydrates (WRC) (similar to holocellulose)

tion, and for control trees; but higher and significant for moderate fertilization with $r = 0.75$. Thus, it appears that initial specific gravity may be but slightly associated with the changes brought about by fertilization.

Cellulose Yields

Neither the water-resistant carbohydrates (WRC) nor alpha-cellulose percentages were significantly affected by fertilizing. Although Figs. 2 and 3 suggest that fertilizers may have some influence on these properties, the observed differences are not statistically significant. Several covariants were taken into account, including growth rate and initial cellulose yields before fertilization, but none of them helped to establish significance of fertilizer effects.

However, in the course of analysis, the difference in WRC between plots showed up as significant at the 5% level. Similar significant differences in cellulose yields were encountered by Zobel, Thorbjornsen, and Henson (*13*), though appearing wholly random in nature. It is,

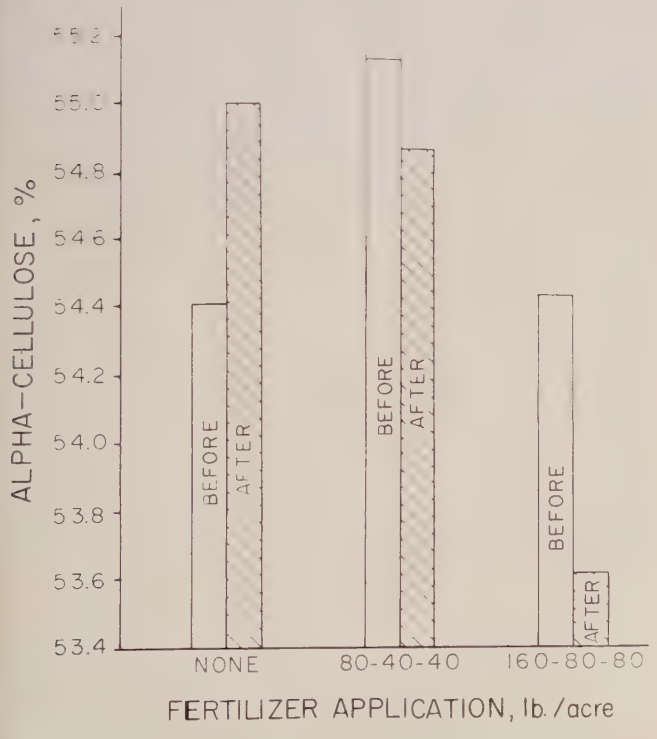

Fig. 3. Effect of fertilizer on alpha-cellulose

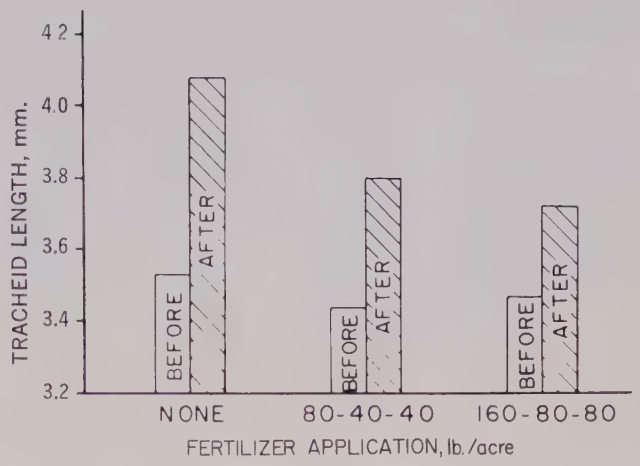

Fig. 4. Effect of fertilizer on tracheid length

of course, possible that some subtle soil–site or habitat differences, undetectable by ordinary availability or stoichiometric soil analyses, may bring about chemical differences in wood constituents. In the present study, with minor exceptions, the soil 5 years after the last fertilizer application appeared to be the same as the unfertilized plots in pH, organic matter, and available Mg, K, P, and Ca, regardless of treatment.

Correlation coefficients between cellulose yields of individual trees before fertilization and changes after application were negative and significant at the 1% level. For the heavily fertilized tree samples, the correlation coefficient was -0.78. An r of this magnitude would seem to indicate that the initially higher yielding trees were less changed than the initially lower-yielding trees by the application of heavy fertilizer.

Tracheid Length

No significant difference in tracheid length were observed that could be clearly ascribed to fertilizing, although a statistically nonsignificant trend toward shorter tracheids with heavier fertilizing appears in Fig. 4. While the analysis of variance failed to establish significant differences between treatments, differences between trees and between plots were significant at the 5% level.

When correlation coefficients between tracheid length *before* fertilizating and changes after application were calculated, significant negative r values were obtained. These data suggest that trees with longer tracheids prior to treatment suffered less attrition in tracheid length than those with initially shorter tracheids.

Variation Among Trees

Numerous studies have already shown large variations in wood properties among trees of the same age on the same site. This large variation can be accepted as a fact. The range in values obtained among individual trees for each treatment is quite wide (Table I). Differences are found in total spread among individual trees within plots but remain about the same magnitude both before and after fertilization. Thus, on the basis of the 67 trees sampled in this study, fertilizers appear not to have appreciably changed the individual tree variability. This observation holds even for specific gravity which heavy fertilization caused to drop sharply in average value for practically all trees in both replications.

Table II. Change in Specific Gravity of Individual Trees Following Fertilization Arranged in Order of Increasing Specific Gravity Prior to Fertilization

	No fertilizer (control)			*Moderate fertilizer (80–40–40)*			*Heavy fertilizer (160–80–80)*		
Tree	*Before*[a]	*After*[a]	*Amt. change*	*Before*[a]	*After*[a]	*Amt. change*	*Before*[a]	*After*[a]	*Amt. change*
1	0.41	0.44	+0.03	0.43	0.45	+0.02	0.44	0.44	...
2	0.42	0.46	+0.04	0.46	0.44	−0.02	0.45	0.41	−0.04
3	0.43	0.42	−0.01	0.46	0.46	...	0.45	0.41	−0.04
4	0.44	0.44	...	0.46	0.47	+0.01	0.45	0.41	−0.04
5	0.45	0.44	−0.01	0.46	0.47	+0.01	0.45	0.42	−0.03
6	0.45	0.46	+0.01	0.47	0.46	−0.01	0.46	0.40	−0.06
7	0.46	0.45	−0.01	0.46	0.48	+0.02	0.47	0.43	−0.04
8	0.47	0.47	...	0.47	0.47	...	0.48	0.44	−0.04
9	0.47	0.48	+0.01	0.47	0.48	+0.01	0.49	0.42	−0.07
10	0.47	0.48	+0.01	0.47	0.49	+0.02	0.49	0.44	−0.05
11	0.46	0.51	+0.05	0.48	0.48	...	0.48	0.48	...
12	0.50	0.49	−0.01	0.49	0.46	−0.03	0.49	0.47	−0.02
13	0.51	0.47	−0.04	0.49	0.48	−0.01	0.50	0.42	−0.08
14	0.50	0.52	+0.02	0.49	0.49	...	0.50	0.45	−0.05
15	0.51	0.49	−0.02	0.50	0.48	−0.02	0.50	0.46	−0.04
16	0.51	0.52	+0.01	0.50	0.48	−0.02	0.51	0.45	−0.06
17	0.52	0.51	−0.01	0.51	0.49	−0.02	0.51	0.48	−0.03
18	0.51	0.54	+0.03	0.52	0.46	−0.06	0.52	0.50	−0.02
19	0.51	0.55	+0.04	0.52	0.49	−0.03	0.55	0.54	−0.01
20	0.52	0.53	+0.01	0.52	0.50	−0.02			
21	0.52	0.53	+0.01	0.52	0.50	−0.02			
22	0.53	0.51	−0.02	0.53	0.51	−0.02			
23	0.53	0.54	+0.01	0.54	0.49	−0.05			
24	0.54	0.55	+0.01						
Average	0.484	0.489		0.486	0.475		0.479	0.442	

[a] Compares wood produced 7 years prior to and 7 years following the first fertilization.

Table II further emphasizes the effect of fertilization on the specific gravity of individual trees. In the non-fertilized or control plots, some trees increased in specific gravity during the last 7 years, and some decreased in specific gravity. About two-thirds of the trees decreased in specific gravity following moderate fertilization, though, for the most part, the decreases were small. On the heavily fertilized plots, not a single tree increased in specific gravity during the seven years following fertilization, though the specific gravity of two trees remained the same. The amount of decrease on most trees was considerable, with a maximum decrease of nearly 16%.

It is of interest to speculate on why all trees did not react alike to heavy fertilizer applications. It is clear for the 160-80-80 treatment that the magnitude of change was not dependent on the original specific gravity of tree (Table II). For example, a tree with a "before" specific gravity of 0.46 dropped by 0.06 following fertilization, while another tree with an initial value of 0.51 dropped by a like amount. The observed responses pose the question as to whether certain individual trees are more "susceptible" to change by fertilizer than are others. Are there genetic types that react to fertilizer while others are essentially stable? The same question is also of importance in the effects of fertilizer on tree growth. There is some indication that the growth response of certain trees to fertilizer application is much greater than for others of the same age on the same site.

Table III. Growth Rates of Planted Loblolly Pine as Affected by Fertilizer Treatment

	Heavy fertilizer 160–80–80	*Moderate fertilizer 80–40–40*	*No fertilizer check*
Diam. of trees, in. (1958)	8.72	8.60	8.14
Radial growth,[a] in. (1951–58)	2.28	2.10	1.71
B. A. Increase per tree, sq. ft. (1951–58)	0.159	0.147	0.112

[a] Doubtless in part because of very large differences among plots, coupled with limited replication, these observed differences between treatments did not prove to be statistically significant.

These postulations cannot be confirmed by the limited data reported here; but the possibility that such physiological–genetic reactions exist among trees is intriguing. If fertilization were to become a standard practice in forest stands, perhaps any increased yields through the use of fertilizers could be enhanced by taking advantage of trees that are genetically able to respond to the increased nutrient supply added from commercial sources.

Growth Rate and Nutrient Conditions

As mentioned earlier, the present study was aimed primarily at determining the effect of fertilizer on wood properties. Some information was obtained on growth effects through fertilization, but no major summary will be made in the present report. In 1961, the 10-year growth measurements will be made for all plots in the plantations including the heavy, intermediate and control plots on which wood was analyzed for this study.

Table III and other previous studies show that (Smith & Dubow (*16*), and unpublished data) fertilized trees have consistently shown faster basal area growth than have the unfertilized ones. Analysis of variance showed after that there was no significant difference in radial growth fertilization between treatments. Nothing can be said about volume growth increase since height measurements in this exploratory study were not taken. Although the heavily fertilized plots had a little more open stocking (19 trees on two plots compared to 23 and 24 for the moderate and the control plots), it is assumed that a portion of the growth differential between treatments is ascribable to fertilizing. This increase, if real, would tend to offset the total cellulose production loss from the lowered specific gravity.

DISCUSSION

The results at this study are somewhat similar to those reported by Erickson, *et al.* (*1*), who observed a decrease in specific gravity due to fertilizing but a greater decrease when fertilizers and thinning were combined. Their study on Douglas-fir was made on a

poor site whereas the present study was for a site index about average for the Piedmont. Results were similar to those of Paul and Marts (*5*) who found that application of a complete fertilizer on longleaf pine increased springwood and decreased summerwood, thus probably reducing specific gravity. When irrigation was added they reported a marked increase in the percentage of summerwood, thus probably increasing specific gravity. However, they found that the application of nitrogen alone increased summerwood more than springwood. The same effect of additional N was reported by Pechman (*8*).

Based on studies reported to date, then, the picture is not clear for older trees. It would seem that high levels of complete fertilizers tend to reduce specific gravity, as found in the present study. However, under certain circumstances N alone, or balanced fertilizers with increased moisture, growing space, or both, results in higher specific gravities. It is futile to hypothesize too much since so few studies have actually been reported; but one thing seems clear, however, the subject is sufficiently complex to preclude simple assessment of the effects of various factors by themselves. Quite opposite results may be obtained if additional environmental factors are brought to bear.

The present study does make it abundantly clear that, despite average changes, large individual variability still exists, thus enabling use of individual tree differences. The usual tendency to assess average values without taking into account the effects on individual trees is not only fruitless but can be grossly misleading. Reports on the effects of treatments on one or two individuals (which may be fast or slow growing, have initially high or low specific gravity or have initially long or short tracheids), thus, are frequently very limited in their usefulness, such results having no general application.

For tracheid length, the differences between treatments were not statistically significant for shorter tracheids with increased fertilization, though a trend appears to be evident. A tremendous amount of tree-to-tree variability was present making it difficult to distinguish real differences between treatments. Wardrop (*4*) showed a drastic shortening of tracheid length following fertilization with superphosphate. To the authors' knowledge, no other results of the effects of fertilizer on coniferous tracheids have been published.

Results for both types of cellulose showed a slight trend for a reduction of cellulose with increased fertilization, but none of the differences were statistically significant. This finding is in contrast to that of Erickson, *et al.* (*1*), who reported a marked change in cellulose yields with fertilizer treatments and thinning.

As has been reported by several investigators, radial growth showed a definite increasing trend with the heavier fertilizer treatments. Again, although the average differences appear to be large, the study did not provide a basis for showing statistical significance among the differences.

For the age, site, and growing conditions of loblolly pine reported here, and for the particular type of fertilization used, heavy fertilization has, by decreasing specific gravity, reduced the amount of cellulose available per unit volume of wood. How much of this decrease will be compensated for by increased volume growth cannot now be stated. However, the 10-year measurements to be made next year will throw some light on this question.

SUMMARY

The effect of certain fertilizer applications on some wood properties of planted loblolly pine were investigated for plantations which are situated on the Hill Forest in Durham County, N. C. In 1958, the effects of three levels of fertilizer were assessed; namely, 160-80-80 lb. of N, P_2O_5, and K_2O (designated "heavy"), 80-40-40 (called "moderate"), and none (check). Fertilizer was applied for three consecutive years, starting in 1951 when the trees were 16 years old. Wood was analyzed for the 7 years prior to first fertilization and 7 years following first fertilization.

Specific gravity of the wood was found to be significantly decreased (up to a maximum of 16%) by the highest level of fertilization (160-80-80). At the more moderate level (80-40-40) specific gravity was also decreased but not so drastically as for the heavier fertilizer application.

Tracheid lengths and cellulose yields both showed considerable trend for decreasing values with increased fertilizer levels, but none of them proved to be statistically significant. Large variability and the relatively small numbers of trees (24) per treatment probably accounts for this.

The large amount of individual tree variability existing before fertilization was still evident following fertilization, even though average figures were considerably changed by the fertilizer treatments.

There appears to be a large amount of individual tree difference in response to fertilizer treatments. This "individual response" may become very important in the development of improved strains of trees. Also, tests made on specific gravity, tracheid length, and cellulose yields show that there may be some differential effect of fertilizer depending on the initial wood properties of the tree. These indications definitely point up that more definitive studies need to be made as to differential fertilizer effects on individual trees.

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Variation in Density and Fiber Length in Wood of Yellow Poplar

EYVIND THORBJORNSEN

This study was conducted to determine if differences in wood properties among yellow poplars (*Liriodendron tulipifera*) in east Tennessee and southeast Kentucky were large enough to encourage a breeding program based on individual tree selection. Data from 10 stands and 63 individual trees are included in this study. The density increased from the inner core to the outer wood; at 5 years the average was 0.42 g./cc., at 15 years 0.45, and at 25 years 0.46. Results from extraction with alcohol-benzene indicate that the main difference between sapwood and heartwood is due to the stains present in the heartwood. On an average 2.5% of the dry matter was removed in the extraction process; this amount did not vary in the radial direction. The component of the total variation in density which the individuals account for is large, being about 70%. Relatively rapid improvement will probably be made by selection for high density due to the large individual tree variation and a good relationship between core wood and mature wood (r = 0.731). During the first few years of growth there is a marked increase in fiber length which tends to level off in later years. Differences among trees with short and long fibers are large, but the analysis of variance indicates that they are not significant due to a large within-tree variance component. This within-tree component can be reduced by measuring a larger number of fibers and taking more care in sampling the same portion of a given annual ring.

Studies of wood properties in several species of pine have shown that a great amount of variation exists among trees. In natural populations of loblolly pine Zobel, *et al.* (*6*), found that the among-tree variation for both density and tracheid length was highly significant. In some instances this type of variation is so large that it is difficult to show significant differences among stands from different physiographic regions. Individual tree variation will be the basis for a large proportion of the improvement which tree breeders hope to obtain through selection. It is encouraging to note that for wood properties in pine there is ample evidence of wide variation among trees. The present study was conducted to determine if differences in wood properties among yellow poplars (*Liriodendron tulipifera*) in east Tennessee and southeast Kentucky were large enough to encourage a breeding program based on individual tree selection.

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MATERIALS AND METHODS

Outstanding phenotypes of yellow poplar were selected in east Tennessee and southeast Kentucky at elevations between 1500 and 2000 ft. Five dominant crop trees, growing on the same $^1/_5$-acre plot as the selected tree, were used for purposes of comparison. Thus, each group of trees consists of six individuals, all of the same age and growing under very similar environmental conditions. To date, 13 trees have been selected; of these, three did not grow in a yellow poplar stand and thus did not have crop trees for comparison. As a result, the reported study includes a total of 63 trees.

Wood samples were taken with an 11-mm. increment borer at breast height (4.5 ft. from ground level). A single core was extracted from the crop trees, while two cores were taken from opposite sides of the selected trees. In the laboratory the cores were divided into three pieces: (a) from the pith to year 10, (b) from year 11 to year 21, and (c) from year 21 to year 31. Wood produced after 31 years from the pith was not included in this study.

The density of each core section was determined as grams of dry weight per cubic centimeter of green volume. The volume was determined by measuring the length of the section to the nearest 0.1 mm. and using the cylinder formula. Check measurements with water displacement indicates that the cylinder method of volume determination yields comparable results.

It was expected that inclusion of compounds other than the celluloses and hemicelluloses may affect density determinations. The Soxhlet extraction apparatus was used to remove a large proportion of these compounds. Wood samples were extracted for 16 hr. in an alcohol–benzene solution (*1*), then for 16 hr. with acetone.

Thin disks of the cores were cut off at ages 1, 11, 21, and 31. These samples were macerated in a half-and-half solution of 10% chromic and 10% nitric acid. The lengths of 20 undamaged fibers were measured from each sample by the aid of the Rayoscope*. Gelatinous fibers were not measured.

* Rayoscope, 358 N. Sandusky St., Delaware, Ohio.

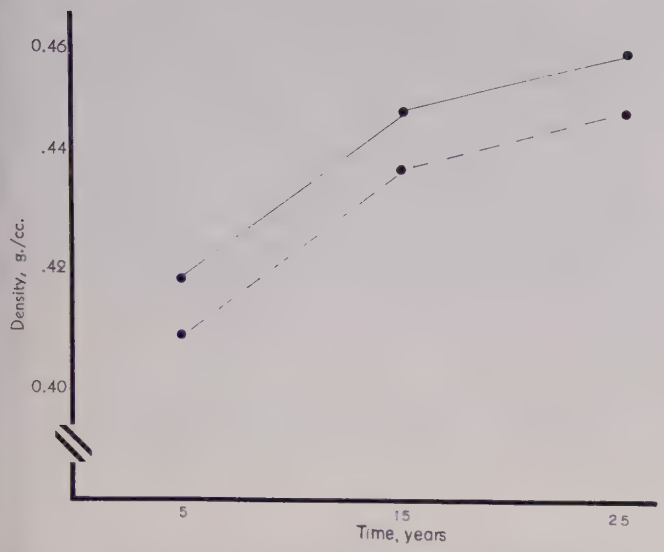

Fig. 1. Radial distribution of average density before extraction (solid line) and after extraction with alcohol–benzene and acetone (broken line)

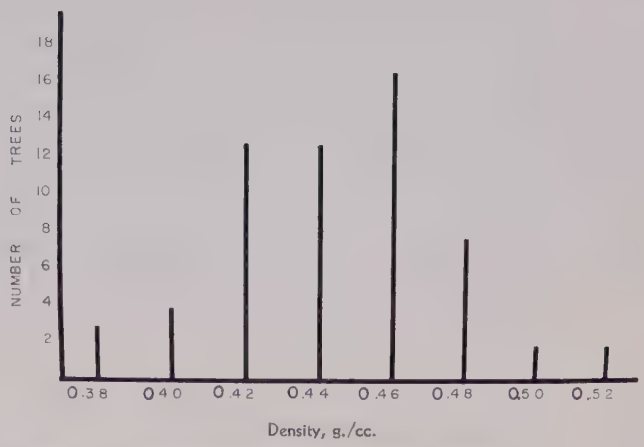

Fig. 2. Frequency distribution of density for non-extracted wood samples representing the growth from 10 to 20 years from the pith

In order to detect significant differences among trees or among stands, the data were analyzed according to the nested analysis of variance. The IBM 650 computer was used for this purpose. Since two samples were taken from only one of the six trees in any stand, some computation was necessary to estimate the variance components. Similarly, adjustments had to be made in degrees of freedom in the F-test (*5*). A considerable reduction in field and laboratory work resulted by using only one sample from all but the selected trees, but this is partly compensated for by added complexity in the statistical analysis.

RESULTS

Density

The density increased from the inner core to the outer wood. The density averaged 0.42 g./cc. at five years, 0.45 at 15 years, and 0.46 at 25 years. There is a strong indication that a leveling-off takes place after 25 years of age. Barefoot (*2*) found that a maximum density was obtained at about 45 years in yellow poplar and that a subsequent decrease in density took place with increased age. Figure 1 shows the radial distribution of average density for both extracted and nonextracted wood.

The two curves are parallel; no greater amount of material was extracted from the inner heartwood than from the outer sapwood. Samples representing the inner 10 rings consisted of heartwood only, the last 10 rings were all sapwood, while the middle 10 growth rings had varying amounts of heartwood and sapwood. Results from the extraction process indicate that the main difference between sapwood and heartwood in yellow poplar is due to the stains present in the heartwood. This result confirms the work by Erickson (*3*) who found that there was no important difference between the density of sapwood and heartwood.

Figure 2 indicates that the densities of individual trees are normally distributed and that considerable differences exist among trees. The analysis of variance (Table I) shows that highly significant differences are present among individual trees growing within the same $^1/_5$-acre plot. The component of the total variation which the individuals account for is large (Table II), being about 70%.

There were no significant differences in density among stands. This finding does not support the report by Barefoot (*2*) that density decreases with an increase in site index. The component of variance accounted for by stands on different sites is negligible. Since site conditions and diameter growth rate within a stand were quite uniform, it is probable that the large differences present for density may be due to strong genetic control of this characteristic.

In any breeding program with forest trees it is of advantage to work with characteristics which can be determined at an early age of the progeny. If a strong relationship is present between density of saplings and more mature trees, it may be possible to make rapid progress in breeding for this characteristic. To test this, the correlation coefficient r was computed for density at 5 years and 25 years (Table III). About 50% of the total variation was accounted for by this relationship, indicating that selections for high density trees may be made at an early age in the F_1 and later generations.

Fiber Length

Figure 3 shows the radial distribution of average fiber lengths from the pith to age 31. The pattern is much the same as for density; i.e., during the first few years of growth there is a marked increase which tends to level off in later years. This pattern has also been found in loblolly pine (*6*).

The frequency distribution of fiber lengths forms a

Table I. Analysis of Variance Estimating the Mean Squares for Determinations, Trees, and Stands

Source of variation	*Model df*	*Mean square estimated*	*Density, g./cc. (not extd.)* 5 Yr.	*Density, g./cc. (not extd.)* 25 Yr.	*Density, g./cc. (extd.)* 5 Yr.	*Density, g./cc. (extd.)* 25 Yr.	*Fiber length* 11 Yr.	*Fiber length* 31 Yr.
Stands	9	$\sigma_D^2 + 1.29\sigma_T^2 + 7\sigma_S^2$	0.167655 N. S.	0.190887 N. S.	0.116452 N. S.	0.156456 N. S.	0.7618425[b]	0.3635170 N. S.
Trees in stands	50	$\sigma_D^2 + 1.14\sigma_T^2$	0.123702[a]	0.125499[a]	0.115327[a]	0.128725[a]	0.2261679 N. S.	0.2588556 N. S.
Determinations	10	σ_D^2	0.006995	0.030400	0.022875	0.037635	0.1412115	0.2469880

[a] Significant at 0.1% level.
[b] Significant at 5% level.

Table II. Variance Components in Per Cent for Determinations, Trees, and Stands

	Density (not extd.)		Density (extd.)		Fiber length	
	5 Yr.	25 Yr.	5 Yr.	25 Yr.	11 Yr.	31 Yr.
Stands	3	6	(−) 1	2	26	6
Trees	91	69	78	67	25	4
Determinations	6	25	23	31	49	90
Total	100	100	100	100	100	100

Table III. Correlation Coefficients for Density and Fiber Length

Relationship				r-Value
Density	5 years	× Density	25 years (not extr.)	0.731[a]
" "	5 years	× " "	25 years (extracted)	0.649[a]
" "	5 years (not extr.)	× " "	5 years (extracted)	0.961[a]
" "	25 years (not extr.)	× " "	25 years (extracted)	0.982[a]
" "	25 years (not extr.)	× fiber length	31 years	0.120 N. S.
" "	5 years (not extr.)	× " "	11 years	−0.144 N. S.
Fiber length	11 years	× " "	31 years	0.210 N. S.

[a] Significant at 0.1% level.

typical normal curve (Fig. 4). Differences between trees with short and long fibers are large, but the analysis of variance (Table I) indicates that they are not significant because of a large within-tree variance component. This latter component accounts for 49% of the variation at 11 years and 90% of the variation at 31 years (Table II). The large within-tree component is partly due to two errors in sampling. One is that a large number of fibers are required to obtain good estimates of means, and the other is the difficulty in sampling the same portion of a given annual ring in this diffuse-porous species.

By more intensive sampling it is probable that statistically significant differences among trees will also be detected for fiber length. It appears from the data obtained, however, that the among-tree variance component will always be relatively small, and only little improvement can be expected in breeding for this characteristic. In addition to much variation within a tree there is good evidence that the quality of site affects fiber length in yellow poplar, especially in young trees. Fiber length at 11 years varies significantly among sites (Table I). At 31 years these differences have disappeared, indicating that fiber length is influenced by site quality during the period of early, rapid diameter growth. A similar relationship has been found for loblolly pine.[1]

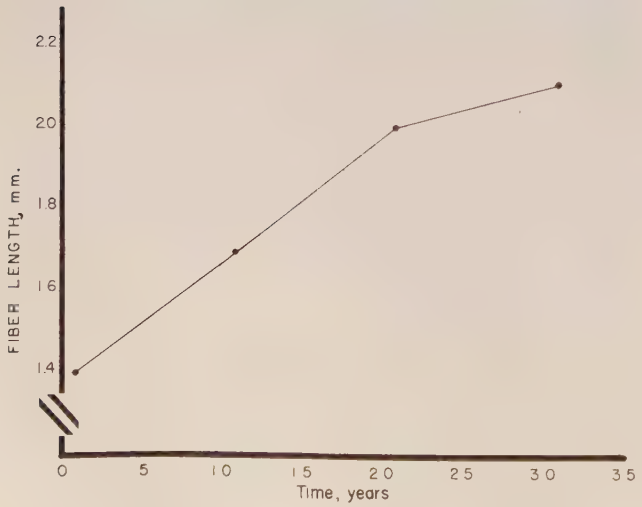

Fig. 3. Radial distribution of average fiber lengths

This relationship between site quality or growth rate and development of fibers makes it difficult to predict the length of "mature" fibers from samples of young trees. In the present study no significant relationship was found between fiber length at 11 years and fiber length at 31 years (Table III). Also, density could not be used as an indicator of the length of fibers.

CONCLUSIONS

The among-tree variance component for density in yellow-poplar accounts for about 70% of the total variation present. Relatively rapid improvement will probably be made by breeding for high density since selections in the F_n generations may be made at an early age (approximately 10 years). Since the more important strength values are closely correlated with density (*4*), a considerable improvement in wood quality may be expected by selection for this characteristic.

Fiber length varies widely within any one tree. The among-tree variance component is small and insignificant, and the fibers produced during the first years of

[1] Personal observations.

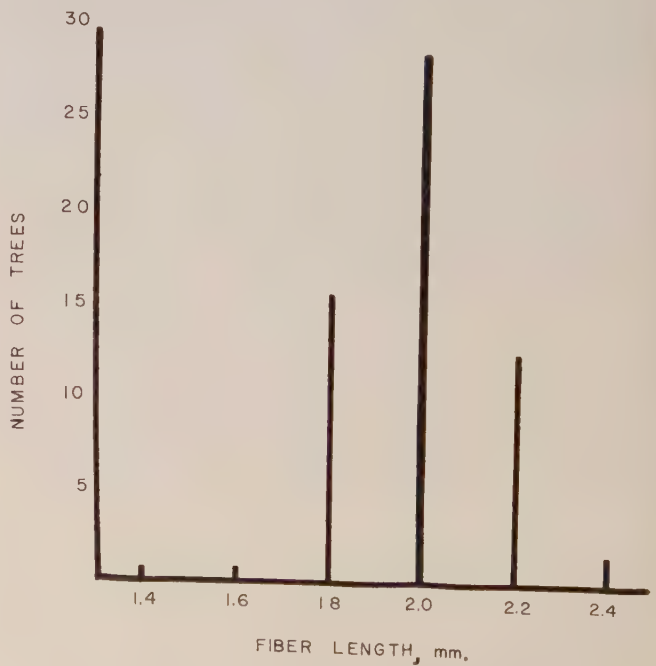

Fig. 4. Frequency distribution of fiber lengths at 21 years from the pith

rapid growth are strongly affected by environmental conditions. Selection for long fibers in yellow poplar will not likely result in a marked increase in timber quality.

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Pulp and Paper Processes and Their Characteristic Differences

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The relationship of wood fiber characteristics to the properties of the finished paper is pointed out. The heterogeneity of the raw wood affects the pulping, bleaching and refining procedures. Also, the use requirements of the end product govern the whole pulping and finishing sequence. The three types of pulping, sulfite, kraft and neutral sulfite, are discussed along with modification of these processes.

The final properties of a paper, or a paper product, reflect the sum total of the attributes and qualities of the original fibers in wood form, coupled with the processing and treatment history, and the designs and intentions of the manufacturer in arriving at the desired use requirement of the ultimate product. In the earlier stages of the development of our industry, fibrous sheet material such as paper, more or less as made, was introduced into new useful applications and functions, and markets were thus developed. As these indicated uses expanded, special qualities and use requirement features were demanded, and as is typical of our economy, the producer was forced to modify his manufacturing techniques to meet these new requirements. It is significant to note that 50 years ago, the major products of this industry were writing and printing papers, with rags and the waste from the textile industry as the major raw material. Papermaking was then considered an art. With increased demands for paper in other use fields, the supply of fibrous raw material became a limiting factor, and technology assisted and gradually replaced the art approach to manufacturing and the development of raw material sources to meet the new demands. It is also significant to note that TAPPI was organized a little over 40 years ago by a few chemists and engineers for the purpose of "furthering the application of sciences in the pulp and paper industry; promoting investigation, research and interchange of ideas among its members; and for the collection and dissemination of information relating to the pulp and paper industry." We are all well aware of the growth of the industry and TAPPI during this period, and a glance at the yearbook will show the multitude and diversity of interests within this group and their organized committees. We must pay tribute to the accomplishments of the various groups within this industry, in the expansion and diversity of the paper and paperboard markets, in the development and advances in paper manufacture and pulp technology, and in the quest for sources of fibrous raw material to meet these needs. It is difficult to suppose, however, that the founders of TAPPI in 1915 could have possibly foreseen or even imagined that by 1960, one of their committees would sponsor a Forest Biology Conference with a theme "Better Fibers from Better Trees Through Forest Biology."

By organizing the Forest Biology Committee, TAPPI has recognized the need for a mechanism of exchange of technical knowledge and understanding between foresters and forest scientists who are growing and seeking to improve trees for the industry's raw material, and the technologists in the industry who are familiar with the fiber properties and processing behaviors which are significant and fundamental in pulp and papermaking requirements. In effect we are attempting to extend the technical and scientific control of our pulp processing and paper manufacturing into the area and realm of the genesis of our raw materials. With our busyness and preoccupation in research, development, and manufacturing of wood to final product, those of us not in or near the forest tend to forget that pulp and chemical wood fibers were once the cells of living trees; that these cells or fibers are of vegetable origin and a vital link in the carbon cycle of the vegetable and animal kingdoms of our planet; and that we have a replenishable source of raw material.

The expansion of the industry more or less followed the general industrial expansion and population growth of the country, under the limitation that the geographical location of the fibrous raw material or the forested areas of the country was a primary controlling factor. Thus it was that, historically, the industry started in the northeast and gradually expanded to the Lake states, the southeast, the northwest, the southwest and finally, further north into Canada and Alaska. This movement brought into use many new wood species indigenous to these areas, with spruce and balsam the

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select species of the northeast and Lake states, the southern pines in the south, and western hemlock and the white firs on the west coast. As the need for fiber increased other conifers, formerly considered less desirable were brought into use, along with the hardwoods in nearly all geographical locations. The development of new paper uses and markets and the use of new wood species went along simultaneously with changes and improvements in pulping technology and paper manufacture. Sulfite pulping with its relatively easy bleaching qualities was limited to the handling of certain selected wood species, but the pulp qualities were adaptable to the finer grades of writing, printing, and specialty papers as well as in the many uses in the dissolving and chemical conversion fields. The chemicals used in sulfite pulping were relatively inexpensive and could be economically expended with the dissolved wastes, but the waste liquor disposal problems and the resulting water pollution difficulties of sulfite pulping were to remain deterrent factors in sulfite expansion until efficient sulfite recovery systems were developed. Alkaline pulping, originally used on hardwoods by the old soda process, gradually developed into the alkaline sulfate or kraft process. The alkaline process was applicable to nearly all wood species, but the processing chemicals were relatively expensive and had to be recovered and re-used for economical operation. Originally, too, kraft pulps were difficult to bleach and the fiber found its major uses in wrapping, bag paper, linerboard and coarse paper specialties, although all of these uses developed into very large tonnage items. Recovery systems were developed for the kraft process, not only for the chemicals, but for the simultaneous recovery of the organic residues for heat and power generation. Neutral sulfite semichemical pulping, which used relatively smaller amounts of chemical for higher yields of pulp was particularly adaptable to the hardwoods. The resulting neutral sulfite pulp could be bleached and found some desirable uses to supplement the dwindling or limited expansion of sulfite pulping in the northeast and middle west. A very large tonnage development for the neutral sulfite semichemical hardwood pulps was in corrugating medium, with improved use qualities over kraft, and the waste liquor recovery difficulties could be overcome by tying-in the liquor recycling with existing kraft recoveries.

It is not the purpose of the present discussion to review production statistics of the various pulp grades; these figures are readily available in the APPA reports and the trade publications. For the present discussion, it is important to note, however, that in the decade following World War II, the total wood pulp capacity of the United States rose from 12 million tons in 1946 to 26 million tons in 1957. A breakdown of this growth in chemical pulps shows that sulfate or kraft capacity increased from $5^1/_2$ million tons in 1946 to $13^1/_2$ million tons in 1957; and sulfite increased from 3 million tons in 1946 to slightly over 4 million tons in 1957. Approximately $3^1/_2$ million tons of neutral sulfite capacity from the hardwoods was added during this 10-year period. The rapid growth of the kraft process is due primarily to the fact that new wood species were available for pulping, which could only be pulped commercially by the kraft process. A secondary reason for this growth was that the kraft process has highly developed chemical and waste recovery systems. The rapid growth of the neutral sulfite semichemical process reflects the availability and utilization of new hardwood species as an excellent raw material for the medium in corrugated board. In addition to chemical wood pulps, the industry reclaims between eight and nine million tons of wastepaper each year, and also produces about four million tons of mechanical wood pulp. Both of these segments of the industry are important sources of fiber but from the viewpoint of forestry, forest genetics, and biology the various factors and considerations for chemical wood pulps would also apply to reclaimed fiber and mechanical wood pulp, so that these two items will not be specifically reviewed in our subsequent discussion.

The theme of the fourth session of this Forest Biology Conference is "Influence of Wood and Fiber Properties on Pulp and Paper Characteristics." As a background for subsequent discussions on pulpwood properties and inherent fiber properties of our various wood species, we have been asked to review the "Pulp and Paper Processes and Their Characteristic Differences." The foregoing comments cover very briefly the development of pulping processes to meet the economic market demands with the fibrous sources that are potentially available. It should be recognized that with the great diversity of papers and paperboards and their multitude of functions and use requirements, no single fiber type or species can adequately meet all these needs to the best advantage. Specified qualities in one paper grade or product are the direct antithesis of the desired qualities in another. Certain writing and printing papers may require very high brightness and opacity with good surface texture and with moderate structural strength, whereas most grades of commercial wrapping and shipping containers require the ultimate in structural and impact strength with color and smoothness being of secondary importance. Some paper products require softness and absorbency while on the other extreme we have products requiring hardness, snap, and stiffness or with a minimum of water and grease absorption. For this reason, a rather broad variety of pulp types are required in the industry. Fiber structure and morphology of the original wood, the type and nature of the cooking and bleaching conditions, plus the mechanical refining conditions and machine operation and treatments all have a bearing in bringing out the desired product qualities. Some wood species are more amenable to this processing and treatment than other species in arriving at the desired qualities.

In many cases, to meet the specifications and use requirements in a given paper product it is necessary to blend different fibers and make up furnishes of various mixtures of sulfite and kraft, conifers and hardwoods. Many paper mills are self-contained; that is, they have their own pulp mills coupled with their paper mills. This has certain economic advantages with convenient transportation of raw materials. However, except for very large installations it is not feasible to install a diversity of bleaching and cooking combinations to satisfy one production unit. Other paper mills have no pulp production capacity at

all and rely completely on market pulps. This is particularly true of specialty papers and despite some economic disadvantages there are definite advantages in being able to select a broad variety of fibrous raw material to meet the specific needs in the manufacture of the special paper products.

In this discussion we can only cover the highlights of pulp and paper processing with the idea of pointing out some of the differences between the various pulping techniques, bleaching procedures, and mechanical refining treatments. The literature on all phases of the industry is very voluminous and quite well documented and no effort will be made to cite references. Our survey will be limited to a brief discussion of the pulping techniques of sulfite, kraft and neutral sulfite, and of the papermaking response of these fibers.

SULFITE PROCESSES

In the sulfite process the wood is digested with an acid solution consisting of a bisulfite with excess sulfurous acid. The most common base for the bisulfite is calcium because of its availability and relatively low cost. The cooking liquors usually consist of 0.9 to 1.3% SO_2 as "combined" (calculated as SO_2 in the form of monosulfite), and the "free" SO_2 as sulfurous acid ranges from 4 to 12% in solution, depending upon the equipment available for the preparation of these cooking liquors. Due to the vapor pressures of these SO_2 solutions, the cooking liquors have to be prepared under pressure, especially at higher concentrations, and elaborate systems have been evolved for recycling the excess gas from the digesters to acid accumulators in order to conserve chemical and heat. The wood chips are usually cooked with "liquor ratios" (weight of liquor to weight of dry wood) of $3^1/_2$ to $5^1/_2$, depending on the degree of packing of the chips in the digesters. Penetration of the wood by the acid is an important feature and with cold acid there is usually a slow temperature rise. With hot acid and with high concentrations and pressures it is possible to effect faster temperature rises. For conventional grades, the maximum cooking temperature may vary between 135 and 140°C, with cooking times ranging from 6 to 14 hr. The cooking pressures depend upon the acid concentration and on the limitations of the cooking equipment, and these pressures normally fall in the range of 85 to 125 p.s.i. Some of the digesters are steamed directly and some are heated indirectly with outside heaters and forced circulation. During the course of the cook some of the liquor may be reclaimed for cyclic acid preparation by taking off a so-called "side relief" and at the end of the cook the pressures are relieved by blowing down to reclaim the excess free SO_2 from the digester. After blowing down the digesters may be actually blown under slight pressure or they may be dumped and flushed into the blow pits or blow tanks. In the conventional calcium-base process, the pulp mass is washed in blow pits and the liquor is discarded. After subsequent knotting and fine screening the pulp is thickened for direct use as unbleached or is then processed in the bleach plant. The degree or intensity of pulping can be varied over relatively wide limits to obtain various pulp yields but in the case of bleached chemical pulp the delignification is carried to such a point that the fibers can be easily separated without mechanical treatment. The optimum fiber strength is preserved, and the material can be readily bleached with economic quantities of chlorine and oxidizing agents. A bleachable grade of pulp is usually cooked to an unbleached yield of 45 to 50%. In the bleaching process additional material is removed giving a final yield of 40 to 45%. In the preparation of purified cellulose further losses in yield occur in the caustic extraction purifying steps so that the final yields may drop as low as 35% of the original wood material. The balance of the original wood substance appears in the waste cooking liquors or in the wash waters from the screening and bleaching operations. Sulfite pulps are relatively easy to bleach and typical bleaching sequences involve three or four stages, namely chlorination, caustic extraction, hypochlorite and chlorine dioxide, or both, and sodium peroxide combinations.

One of the difficulties with sulfite pulping relates to the inability of the process to pulp all species of wood. It has been shown by Erdtman that some woods contain phenolic inhibitors, such as pino sylvin that block the sulfite pulping mechanism. On some species the delignification is slow at normal sulfite temperatures and when attempts are made to raise the temperature one can readily start a catalytic breakdown of the sulfur compounds so that the final delignification is impossible or incomplete. The sapwood or young-growth wood can frequently be pulped by the sulfite process but the heartwood or older wood pulps only with difficulty. In effect, then, the sulfite process is limited to certain select woods which include spruce and balsam, hemlock and the true firs and, under certain conditions, southern pines have been handled in the south. Hot acid cooking systems with high acid strength improve the ease of cooking and permit the handling of some resistant species. More soluble bases such as magnesium, ammonium, and sodium improve the reactivity of the cooking chemical and thus permit the handling of some additional wood species. By the conventional single-stage cooking operation, however, it may be said that the sulfite pulping technique is limited to certain select wood species.

Another limitation of the calcium-base sulfite system relates to the difficulties of waste liquor recovery and the abatement of the resulting pollution effects. A great deal of effort has been directed toward the solution of this problem and, of course, one of the limiting factors is related to the thermodynamics and breakdown temperatures of calcium salts. Other bases have been proposed as a means of getting around these difficulties and we give consideration to more soluble bases such as ammonium, sodium, and magnesium. From the point of view of pulping, both ammonium and sodium are excellent chemicals but here again economic factors control the use of these chemicals unless they can be recovered or their use otherwise justified. Ammonia-base waste liquors are readily evaporated without scaling and can be used to advantage where by-products are recovered. In burning the resultant residues, however, the ammonia is destroyed and cannot be recovered. Soda-base liquors are excellent for pulping and they present no serious problems in evaporation, but in the burning operation the sodium salts are recovered in the form of carbonate and sulfide.

Many schemes have been proposed for reconverting the sulfide to sulfite, but in most cases the complicated steps in this conversion have held up the exploitation of this process. In recent years soda-base processing has been used commercially in Europe and currently a new plant is being built in Nova Scotia by Stora Kopparbegs A.B., Sweden. There are several plants in this country now using the magnesia-base process. The actual pulping conditions in the magnesia-base process are very similar to those of the calcium base. After pulping, the magnesia base liquors are separated from the fibrous mass on multistage vacuum washers, the waste liquors (at about 16% solids) are evaporated in multiple-effect evaporators and finally burned in a special furnace for heat and power generation. The magnesium is separated from the hot flue gases by cyclone separators and dispersed and hydrated to milk of magnesia solution. This solution is then pumped through a series of absorption towers to recover the sulfur dioxide from the combustion gases. The final liquor then contains the magnesium and the sulfur in substantially the bisulfite form necessary for subsequent pulping. Recent new installations have been able to reduce the makeup chemicals to 25 lb. of MgO and about 50 lb. of sulfur per ton of finished pulp.

SPECIAL SULFITE PULPING TECHNIQUES

During the past 50 years many sulfite-type pulping techniques have been proposed, involving both single and two stages of pulping. Many of these involve soda-base liquors and the inherent difficulties have been related to the liquor recovery. Some of these have been tied in with neutral sulfite cooking, which will be discussed later. In recent years there have been two processes which have gained commercial acceptance in Europe known as the Stora process and the Sivola process. There is, currently, a new plant under construction in Nova Scotia, based on the Storaprocess. The Stora process uses soda liquors involving two stages of cooking. In the first stage the chips are digested with bisulfite, or mixtures of bisulfite and monosulfite cooking liquors. After partial digestion, these liquors are drained from the digester, fortified and re-used in subsequent cooks. The chips are then treated in a second stage with sulfurous acid, and the digestion completed. The pulp mass is then separated from the waste cooking liquors by the use of diffusers or multistage washers and the liquors are evaporated and burned. In the Stora system, the sodium salts are recovered in a manner similar to the kraft process in the form of carbonate and sulfide, the sulfides being reconverted to sulfite by a series of chemical steps developed by Stora Kopparbergs. The Sivola process is somewhat similar to the Stora process, as far as the first stage is concerned. After removing the first-stage liquor it can be re-used again for subsequent pulping, and the contents of the digester are treated with an alkaline carbonate or sulfite solution. Here again the sodium salts are recovered in a manner similar to kraft and a reconversion to sulfite is required. Two-stage pulping of both of these types permit the use of wood species which are difficult to pulp by the conventional sulfite process. Introducing two stages of cooking, also, develops different ultimate pulp qualities. The Stora process produces pulp with exceptional strength and very fast beating qualities. The Sivola system produces exceptionally strong pulps with long-beating qualities similar to kraft.

The magnefite process, recently introduced by Tomlinson, is a modification of the magnesia-base sulfite system. In the magnefite process the wood chips are digested with a true magnesium bisulfite solution at a concentration of about 2% combined with 2% free SO_2. The chips are pre-steamed and pre-impregnated and the temperature is raised to between 155° and 170°C. Since there is very little free SO_2 there is very little excess gas pressure. Somewhat harder pulps are produced by this process requiring more bleaching chemical but the accumulator and acid makeup system are simplified since we are not dealing with large volumes of gases under pressure at high temperatures. The magnefite liquor is recovered in a standard MgO system which produces raw acid in bisulfite form.

KRAFT OR SULFATE PROCESS

With this process the chips are digested with an alkaline liquor consisting of sodium hydroxide and sodium sulfide. Almost any kind of wood species can be pulped by this process. Usually 16 to 20% active chemical as Na_2O based on dry wood is charged to the digester and the liquor ratios are adjusted to between $3^1/_2$ and 5. The cooking temperatures normally range from 165 to 180°C with cooking times from 3 to 7 hr., depending on the temperature. The digester contents are blown into a blow tank fitted with blow condensers. Originally, the liquors were separated from the fibrous mass by diffusers but modern American practice usually calls for several stages of counter-current washings. These liquors are then evaporated in multiple-effect evaporators, followed by direct-contact evaporators, and the heavy liquor is then burned in the recovery furnace. The sodium salts are recovered in the bottom of the furnace in the form of a smelt which is re-dissolved to form green liquor. This green liquor consists of sodium carbonate and sodium sulfide as the active chemical. The green liquor is treated with milk of lime, which forms sodium hydroxide and sodium sulfide and which can be used for subsequent pulping after removing the carbonate sludge by settling. The carbonate sludge can be reburned in the lime kiln to form fresh burned lime and milk of lime to complete the cyclic process of chemical conversion and liquor makeup. The makeup chemical for the kraft process is salt cake or sodium sulfate which is fed directly to the furnace with the black liquor prior to burning. The kraft process has a highly developed chemical recovery system coupled with the utilization of chemical residues for power and heat generation. Since considerable steam is used in the evaporation, efforts are made to build up the concentration of the waste liquor by using some of the black liquor in the digester to maintain good circulation and chip coverage. The counter-current vacuum washing systems are also designed to use a minimum of water in balancing good washing with low chemical losses and maximum liquor solids built up.

Kraft pulps were originally used in coarse papers for wrapping, bags, and packaging purposes. The color

of unbleached kraft is quite dark compared to sulfite, and compared to sulfite it is relatively difficult to bleach. However, during the past 25 years elaborate bleaching sequences have been developed for kraft pulps employing anywhere from four to eight stages or more of bleaching. Currently, many kraft pulps are on the market in the brightness range of over 90 G.E. There are numerous combinations of bleaching sequences involving hypochlorite, chlorine dioxide, and sodium peroxide, in the latter stages. The simpler combinations involve chlorination, caustic extraction, hypochlorite, caustic extraction, and a final hypochlorite or peroxide. More elaborate combinations consist of the substitution of some of the hypochlorite stages with chlorine dioxide for the attainment of brightness in excess of 90 G.E.

NEUTRAL SULFITE SEMICHEMICAL PROCESS

The pulping of wood by the neutral sulfite process has been known for years. It consists of digesting wood chips with sodium sulfite buffered with a small amount of alkali carbonate or bicarbonate. This system was promoted by Bradley and McKeefe, and others, some 30 or 40 years ago. For complete chemical pulping of coniferous woods by this process 40 to 50% chemical based on the dry wood is required. This presented a very heavy chemical recovery load and since the system was based on soda liquors the recovery system was similar to kraft except that the inorganic load was very high and the problems of reconverting sulfide to sulfite limited the growth of this process. During the past 10 to 15 years this process has been revived and applied to the semichemical pulping of hardwoods. Since in semichemical we are not attempting to completely delignify the wood, the amount of chemical can be substantially reduced in the case of hardwoods to between 12 to 20% sodium sulfite on the weight of the dry wood. Since the liquors are slightly alkaline, the digestion equipment is very similar to kraft, with cooking times of from 2 to 4 hr. at temperatures of 160 to 180°C. The contents of the digester can be conveniently blown, although the material after blowing is still more or less in chip form since we are dealing with pulp yields of 65 to 78%. In order to reduce the partially cooked and softened chips into pulp form the entire hot mass of chips and liquor are passed through defibrators of the disk type. After defibration by hot refining, the pulp mass is passed over several stages of counter-current washing to clear the pulp of spent liquor. The resulting pulp is usually quite light, depending upon the yield and degree of cooking. These pulps can be bleached in a manner similar to sulfite although the bleach demand will obviously depend on the residual lignin content. The yields of the bleached pulp are high compared to normal sulfite pulping, due to the preservation of the hemicellulosic material, and the resulting bleaching chemical demand is very high. The largest tonnage of semichemical pulp, however, is in the form of corrugating medium. In some plants the waste liquor is not recovered since the higher yields justify the expense of discarding the spent liquors. However, these liquors do contain 20 to 35% of the original wood substance and they constitute a substantial pollution hazard. Many of the neutral sulfite operations are tied in with kraft pulping to supplement a balance of linerboard and corrugating medium production. In this case, the waste liquors are recovered in a manner similar to kraft pulping and are burned with the kraft liquor in the kraft recovery operations. The neutral sulfite process, however, would require fresh liquor makeup and the chemical from the neutral sulfite after recovery would represent the soda makeup for the kraft operation. With this type of balanced system it is possible for the kraft recovery system to absorb the soda from the neutral sulfite on the basis of one ton of neutral sulfite for every 3 to 4 tons of kraft, depending upon pulp yields and recovery efficiency.

PAPERMAKING TREATMENTS AND PULP QUALITY AND CHARACTERISTICS

In all pulping operations the fibers are isolated from the wood structure and prepared for the subsequent papermaking operation. With the possible exception of neutral sulfite pulping, where disk refiners are used for disintegrating the soft chips, the fibers are still in pulp form and still unusable for actual papermaking. The basic pulp is "free", and in order to develop strength and internal bonding, the fibers are treated in beaters or refined in continuous refiners to ultimately arrive at the functional properties of the finished paper. In the case of market pulps after final bleaching, screening, and Centri-Cleaning, the pulp is formed into a sheet similar to paper and dried for shipment. The paper mills then re-slush the pulp and refine it mechanically by beating or jordaning to arrive at the desired paper qualities.

As indicated at the beginning of this discussion, the paper industry covers a very wide panorama of paper products with a wide diversity of use-requirement properties. Outside of the chemical properties, and possibly color and brightness, the strength properties normally considered in pulp evaluation are usually patterned after the strength properties used in evaluating paper. Thus, we speak of Mullen, fold, tensile, tear, and opacity of a pulp under prescribed laboratory testing conditions, when in reality we are trying to translate these numbers to how the pulp will perform in papermaking under a broad variety of refining and manufacturing conditions. The strength properties of a pulp, therefore, are not absolute and are only emperical relations indicating how a pulp will perform under certain paper manufacturing conditions.

In general, sulfite coniferous pulps refine and develop very easily. They form well and they are particularly suitable for high-grade writing and printing papers, or papers with a good printing surface. Sulfite pulps require a relatively small amount of mechanical refinement to develop their strength, particularly when used without drying. In a case of market pulps where it is necessary to dry the pulp and ship great distances the drying effects the balance in the strength properties. After drying, the pulp is more difficult to refine and it requires more time and power to attain the desirable levels of Mullen, tensile, and fold. The tear, on the other hand, is higher in the dried sulfite pulp than in the original wet form. Usually dried pulps are also more opaque than pulps that have never been dried. In the case of greaseproof papers, special sulfites are made which are known as Mitscherlich pulps. This is

a slow-cooked sulfite pulp normally requiring 14 to 18 hr. at maximum temperatures below 120°C. The bleaching of this pulp is very similar to normal sulfite bleaching except that caustic extraction is reduced to a minimum. Normally, Mitscherlich pulps are not dried in excess of 70% airdry, and where possible they are sent directly in slush form to the paper mill. The complete drying of Mitscherlich pulps greatly reduces their ability to form glassine and greaseproof qualities.

In contrast to the Mitscherlich pulps dry sulfites and dry purified sulfites can be made to develop good absorbency, opacity, and softness. These fibers can be cut quite readily in refining to obtain good formation with a relatively free stock.

The Stora-type two-stage pulp can be made into a very fast beating variety similar to Mitscherlich. This pulp can be developed into very slow stock with a minimum of horse power–hour requirements. The Mullen and tensile strengths are high with good fold and good density, but the tear and opacity are sacrificed.

The Sivola-type pulp is a modified form of a purified alpha with good Mullenand tensile strength after proper refining and has the ability to maintain reasonably good tear and opacity after refining. Purified sulfite pulps for papermaking can be made by adjusting the degree of caustic extraction. Here we can produce pulps at various alpha levels but in so doing we sacrifice the development of Mullen and tensile, with improvement in tear, opacity, and bulk. Some hardwoods can be pulped by the sulfite process, and as is typical with deciduous woods we are dealing with very short fibers having a large specific area of fiber surface. Hardwood sulfites, in general, have relatively low strength with excellent forming characteristics. Some hardwood species produce a pulp that have some swelling characteristics and can be hydrated to a dense sheet. On the other hand, some species produce more or less a filler-type pulp with very little internal bonding tendencies but with excellent opacity, color, and forming properties.

Kraft

As a group, sulfate pulps exhibit much higher strength properties than sulfite pulps. On wood species that can be pulped by the sulfate process direct comparisons can be made on the same wood using the two different processes. The conventional pulp quality tests such as Mullen, fold, tensile, and tear are invariably higher with kraft pulp than with the corresponding fibers in sulfite form. In cases where we can pulp the same wood species by the two different processes, we are dealing with the same fibrous material in the sense of fiber morphology and fiber origin. The two processes must affect the chemical and physical nature of the cellulosic material in different ways to bring about the strength differences, as well as the forming and handling characteristics. Some of these properties, such as flocking tendencies and formation properties, are difficult to measure and express numerically. However, anyone familiar with the handling of the fibers prepared by the two processes can readily perceive the differences in behavior even though absolute tests have not yet been developed for measuring properties attributable to this behavior. When the fibers and cellulosic materials are examined by the conventional cellulose parameters, such as alpha-cellulose, copper number, viscosity, KOH solubility, and D.P. distribution, there is not much evidence to indicate that the cellulose has been damaged by one process any more than the other if proper care has been taken in the pulping and subsequent bleaching operations. However, there are definite differences in the swelling and surface colloidal properties of the fibers which may well account for the strength differences that are normally measured in pulp evaluation. In general, when brought to the same degree of bleaching purification, the kraft pulps have slightly lower yields than the sulfite due to the alkaline nature of the kraft cook. The alpha's are slightly higher with lower KOH solubility for the kraft treatment in contrast with the sulfite. On the other hand, most sulfite pulps develop slowness more readily and require less refining power in stock preparation than the same species treated by the kraft process. Sulfite pulps tend to produce well-formed sheets with good surface texture whereas with kraft pulps there is a tendency for flocking and this results in wild sheet formation with rough surface texture. As indicated above, many of these subtle qualities and behaviors are difficult to measure and interpret with the conventional pulp evaluation tests and much more fundamental knowledge of fiber structure and behavior will be needed before we can fully delineate the differences between sulfite and sulfate pulping even on the same wood species.

Sulfite pulps can be purified with hot caustic treatments to improve the alpha level and thus produce a purified wood cellulose for special papermaking grades and, also, for dissolving pulps. Sulfate pulps, on the other hand, do not respond to hot caustic treatments and the alpha levels are substantially unchanged. However, the alpha levels can be changed on both types of pulp by cold caustic treatment. The chemical reactivity of sulfate pulps is also quite different from the reactivity of the same species prepared by the sulfite process. It is well known that it is virtually impossible to acetylate kraft pulps when treated in a manner similar to sulfite pulps. Reactivity of the kraft pulps can be improved and altered by a prehydrolysis treatment. In the prehydrolysis treatment the raw wood chips are heated in hot water with mineral acid or the organic acids generated *in situ*. The prehydrolysis can also be carried out with steam in the vapor phase since the chips normally contain organic acids or imbibed water. This prehydrolysis treatment which precedes the normal kraft cooking produces a pulp with higher alpha levels and the reactivity of the cellulose is also radically altered. The observation of these phenomena also indicate that there are fundamental differences in the sulfite and sulfate processing treatments even on the same fiber which must effect the fiber as far as their structure in the sense of accessibility to subsequent chemical treatments and the swelling phenomena brought about by mechanical treatments.

Most hardwoods can be pulped by the sulfate process and these fibers can be bleached readily by conventional means. By and large, hardwood krafts produce reasonably good strengths in comparison with the same fibers cooked by the sulfite process. Hardwood sulfates tend to swell in stock preparation to produce dense papers of reasonably good strength and somewhat lower opacity. The forming properties of the hard-

wood krafts are usually quite good and these fibers are used to advantage in attaining good formation and surface texture properties.

Neutral Sulfite

For practical purposes neutral sulfite pulping is applied predominantly to the hardwoods. Bleached neutral sulfite pulp is used as a supplement to sulfite in higher grade printing and writing papers. This pulp can be "hydrated" very easily to produce dense stock with good formation characteristics. For a hardwood fiber the strength features are superior to normal sulfite and compare quite well with kraft.

The bulk of the neutral sulfite production in this country is tied-in with a semichemical production of fiber for corrugating medium. Aside from its low cost, due to the high yield and relatively low chemical demand, neutral sulfite pulp from hardwood produces a corrugating medium with qualities superior to similar mediums made from unbleached kraft or unbleached sulfite. The qualities in question are peculiar to this particular application. These qualities relate to the runnability of the paper sheet on a corrugator in that it corrugates well and forms easily and from a strength point of view the desired qualities relate to the stiffness of the corrugated flutes and the ability to withstand crush pressure. This quality is measured by a test known as a Concora medium test. When judged by this test and, also, by the flat crush of the combined board, medium made by the neutral sulfite chemical process from hardwoods is superior to medium made from hardwoods or coniferous woods by the kraft process. Other strength features of neutral sulfite semichemical hardwood such as Mullen, tensile, and tear are inferior to pulps made by the kraft process, although it is difficult to make direct comparisons since we are dealing with different degrees of delignification and pulp yields.

SUMMARY

In conclusion it must be borne in mind that the properties of the finished paper or paper product is an integration of all of the qualities of the original fibers of the wood. This basic raw material may be hardwood or soft wood, and is an extremely heterogeneous collection of such varying materials as heartwood and sapwood, summerwood and springwood, tracheids and medullary rays, to say nothing of varying amounts of different kinds of decay that may be present. Also, such factors as tree age, rate of growth, growth-site elevation and the effects of rainfall, temperature and soil nutrients, all affect the characteristics of the wood and are necessarily reflected in the finished product.

It is the pulp makers problem to take this heterogeneity and, by the one or more processes which he has available, to reduce the wood to pulp in such a way as to maintain the best possible properties of the original wood fibers. By "best possible properties" we must bear in mind the ultimate use to which the pulp is to be put—be it for writing paper, corrugating medium, absorbent papers, nonabsorbent papers, or for such uses as chemical products as rayon or explosives.

Further, the papermaker must take the pulp so produced and by proper refining, or beating, and by the use of available additives, prepare a stock suitable for handling on his particular machine to make a paper sheet having the qualities which the ultimate consumer requires.

The forest scientist must be aware that in all this there is no one pulping process, one bleaching sequence, one refining system that can handle all the products of the forest to produce the multitude of end products demanded by the final consumer.

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Relationships Between Hardwood Fiber Characteristics and Pulp-Sheet Properties

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This study, based on pulping tests involving 15 highly diversified species of tropical American and domestic hardwoods, was undertaken to determine the effects of hardwood fiber characteristics on strength properties of kraft pulps. To a very substantial degree, pulp properties were found to be related to morphological characteristics of fiber, intrinsic fiber strength, and specific gravity of the wood. Quantitative relationships have been established between individual fiber characteristics, or combinations of characteristics, and specific pulp properties for a broad range of hardwood fibers. Most of these quantitative relationships accounted for 70% or more of the total variation show by all of the pulps in such properties as tensile, burst, and tearing strengths after beating as well as in the unbeaten condition.

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The extent and nature of the influence of the morphological characteristics of wood fiber on the properties of paper have long been the subject of study by numerous investigators in many countries. Yet, even today, we are confronted by a vast void particularly with respect to the quantitative effects of fiber characteristics on pulp-sheet and paper properties. In a report presented at this conference, Subcommittee No. 2 of the Tappi Forest Biology Com-

mittee states that "all fiber dimensions (length, diameter, and wall thickness) are interdependent in a complex and little understood way, and influence many aspects of paper making."

This study was undertaken to determine the effects of such hardwood fiber characteristics as fiber length, fiber diameter, lumen width, and cell-wall thickness on the strength properties of kraft pulps. Fifteen species of tropical American and native hardwoods were selected to provide a wide range of fiber characteristics. The design of the study provided for the pulping of each species by means of a series of cooks of increasing severity and processing each cook in a Valley beater, so that individual species might be compared with one another at a uniform permanganate number and after various degrees of beating. The evaluation of handsheet properties was carried out by means of standard Mullen, tensile, and tear tests. Zero-span tensile tests were also conducted to provide an indirect measure of intrinsic fiber strength that might be found useful in accounting for other pulp properties. Analysis of test results consisted essentially of correlating the pulp-sheet properties of various species with original wood and fiber characteristics.

PREVIOUS WORK

Early literature on fiber dimensions placed great emphasis upon fiber length. Graff and Miller (*1*) have reviewed a number of studies in this area made during the period 1904–1920. Investigators of that day were undoubtedly influenced by the widely held concept that paper strength was associated primarily with long fibers.

Interest in other relationships between fiber dimensions and paper strength was stimulated by the recognition by Strachan (*2*) and Klemm (*3*), in the 1920's, that a derived fiber characteristic—the ratio of fiber length to width—was more significant in its effect upon pulp strength properties than fiber length alone. This ratio, sometimes called "felting power," has found support in several studies for its specific relationship to tearing strength (*4–8*).

In recent years there has come about increasing recognition of the role played by other fiber characteristics—fiber width, lumen width, and cell-wall thickness—in the formation of a pulp sheet (*9–25*). Thin-walled fibers of large diameter collapse to flattened ribbons in the process of sheet formation to form a compact pulp sheet with highly effective fiber to fiber contact areas. Such pulps are characterized by high burst and tensile strengths. Conversely, thick-walled fibers of small diameter resist collapse and retain their tubular shape to form a bulky sheet. Because of the reduced area of contact between fibers, such a pulp is relatively low in burst and tensile strengths. The factors responsible for tear resistance are such, however, that in spite of the reduced area of contact available for fiber-to-fiber bonding, and perhaps even because of it, the tear resistance of a sheet made up of relatively thick-walled fibers is superior to that developed from thin-walled fibers.

Coincident with the development of this concept of fiber behavior, various ratios involving fiber dimensions have been introduced for the purpose of relating fiber characteristics to specific pulp-sheet properties. The flexibility ratio (lumen width/fiber width) has been reported to have a parabolic relationship with breaking length (*4, 5*). The higher this coefficient, the better is the tensile strength. Coefficient of rigidity (cell-wall thickness/fiber width) presumably is also related to tensile strength but in a negative manner (*5*). The Mühlsteph classification (*12*) of fibers in relation to pulp-sheet quality is based on the relative area of cell wall to that of the whole fiber as seen in cross section. Under this classification fibers are grouped according to their collapsibility and consequently to their tend-

Table I. Specific Gravity and Fiber Dimensions of Fifteen Hardwoods Selected for Pulping

Common name	*Scientific name*	*Source*	*Specific gravity*[a]	*Average fiber dimensions, in μ*			
				Length	*Width*	*Cell-wall thickness*	*Lumen width*
Ceiba	*Ceiba pentandra*	Venezuela	0.29	1911 C[b] = 17.6	22.7 C = 13.2	4.9 C = 18.4	12.9
Copaia	*Jacaranda copaia*	Surinam	0.39	1113 C = 13.3	24.7 C = 16.2	3.4 C = 5.9	17.9
Simaruba	*Simaruba amara*	Surinam	0.40	1118 C = 11.6	17.2 C = 16.3	2.3 C = 17.4	12.6
Espave	*Anacardium excelsum*	Panama	0.43	1352 C = 12.6	20.3 C = 12.8	2.9 C = 13.8	14.5
Laurel blanco	*Cordia alliodora*	Panama	0.51	1529 C = 15.9	16.3 C = 22.7	3.8 C = 26.3	8.7
Red gum	*Liquidambar styraciflua*	United States	0.54	2000 C = 14.4	25.0 C = 15.6	7.8 C = 6.4	9.4
Roble blanco	*Tabebuia pentaphylla*	Panama	0.55	985 C = 15.8	15.6 C = 18.4	3.0 C = 19.7	9.6
Red oak	*Quercus* sp. (prob. *falcata*)	United States	0.69	1404 C = 19.4	17.8 C = 17.4	5.4 C = 20.4	7.0
White oak	*Quercus* sp. (prob. *alba*)	United States	0.79	1434 C = 17.0	16.2 C = 16.7	5.3 C = 18.9	5.7
Supupira	*Diplotropis purpurea*	Surinam	0.81	1399 C = 14.7	17.6 C = 15.9	6.8 C = 19.1	4.0
Mylady	*Aspidosperma cruentum*	British Honduras	0.84	1696 C = 14.0	23.8 C = 13.8	8.5 C = 17.6	6.8
Nargusta	*Terminalia amazonia*	Panama	0.85	1696 C = 16.8	13.9 C = 13.7	4.4 C = 18.2	5.1
Jarana	*Holopyxidium latifolium*	Brazil	0.97	1674 C = 15.4	14.3 C = 12.6	6.3 C = 12.7	1.7
Marishiballi	*Licania buxifolia*	British Guiana	1.10	1436 C = 13.8	18.2 C = 12.1	8.2 C = 15.8	1.8
Bannia	*Swartzia bannia*	Surinam	1.16	1014 C = 11.2	14.2 C = 12.0	6.3 C = 12.7	1.6

[a] Based on ovendry weight and volume.
[b] C = coefficient of variation ($\sigma \times 100$/mean).

ency to form low-density or high-density sheets. The Runkel ratio (double cell-wall thickness of the fiber/-lumen diameter) has also received considerable attention as a basis for fiber classification (*11*). The two systems are essentially based upon the same concept and have been found to show good agreement (*6–7*).

In summary, numerous investigations have shown that fiber length alone is inadequate to portray the significant characteristics of fiber in relation to the strength of paper. Appreciable relationships have been shown to exist between specific sheet properties, such as tearing strength and tensile strength, and various ratios derived from fiber dimensions such as diameter, cell-wall thickness, and lumen width, as well as fiber length. Quantitative interpretation of these relationships has been limited, in some cases, by variability in test results; in others, by experimental designs that concerned themselves with a relatively narrow range of fiber characteristics.

The most recent advance in development of the theory of paper strength has been recognition of the part played by the strength of individual fibers (*25, 26*). Intrinsic fiber strength must be taken into account together with fiber characteristics that influence conformability and fiber-to-fiber bonding in attempting to explain pulp-sheet properties in terms of fiber characteristics.

In testing the effectiveness of various combinations of fiber dimensions and intrinsic fiber strength in accounting for variation in pulp-sheet properties, the design of the present study called for a wide range of hardwood fiber characteristics. Homogeneity within a sample was emphasized in the selection of material representing a particular combination of fiber characteristics, and samples for anatomical study were closely matched to the material that was chipped for pulping. Techniques for direct microscopic measurement of fibers from macerated material were selected in the light of Wilson's (*27*) excellent review of methods of fiber mensuration and the recent work of Peel (*28*).

EXPERIMENTAL PROCEDURE AND RESULTS

Determination of the Morphological Characteristics of Wood Fibers

Each of the 15 species was represented by a sample taken from a single plank sufficient in size to yield approximately 10 kg. of dry chips. Homogeneity of the sample was improved by selection so that the experimental material was either all heartwood or all sapwood. All visible defects were eliminated and, in the case of a plank containing the center of the log, material within 2 or 3 in. of the pith was also eliminated. Representative specimens were selected for determination of specific gravity and for anatomical study. Species represented in these tests are arranged in order of increasing specific gravity in Table I.

From each 10-kg. sample at least 4 representative blocks were combined into a composite sample in preparing macerated material for fiber measurement. The composite sample was reduced to fine splints, from which a 1-g. sample was selected at random for maceration by the Spearin and Isenberg (*29*) technique. After dilution to a volume of 1 liter, one or two drops of the fiber suspension were placed on a glass slide and held with a cover slip. Ten whole fibers were chosen at random and measured from each slide. In all, 50 whole fibers were measured from five slides of each species.

Table II. Derived Dimensional Values for Fibers of the 15 Hardwoods Included in This Study

Species	Ratios					Cross-sectional area of cell wall, sq. mm.
	Felting power	Flexibility	Runkel	Mühlsteph	Rigidity coeff.	
Ceiba	84	57	0.76	67	43	27.49×10^{-5}
Copaia	45	72	0.38	48	28	22.78
Simaruba	65	73	0.37	47	27	11.00
Espave	67	71	0.40	49	29	15.71
Laurel blanco	94	53	0.87	70	47	14.92
Red gum	80	38	1.66	86	62	42.41
Roble blanco	63	62	0.63	63	38	11.78
Red oak	79	39	1.41	84	61	21.21
White oak	89	35	1.89	88	65	18.06
Supupira	80	23	3.40	94	77	22.78
Mylady	71	29	2.50	91	71	40.84
Nargusta	122	37	1.73	84	63	12.57
Jarana	117	12	7.41	99	88	15.83
Marishiballi	79	10	9.11	99	90	25.76
Bannia	71	11	7.9	99	89	15.63

The dimensions of each whole fiber were determined using a Leitz binocular microscope equipped with 10-X and 45-X objectives. A revolving stage and Filar micrometer eyepiece facilitated measurement. Fiber width and cell-wall thickness were measured at four sections of each whole fiber: at 0.2, 0.4, 0.6, and 0.8 of fiber length. Average values for fiber dimensions were determined with an error term not exceeding 5% at the 95% level of significance. When measurements of 50 whole fibers were not sufficient to meet this requirement, additional fiber measurements were made. The required number of whole fibers to be measured was determined by the equation:

$$N = \frac{4\sigma^2}{L^2}$$

where

N = the required no. of whole fibers to be measured
σ = standard deviation
L = permissible error, i.e., the average dimension times 0.05.

Table I shows the fiber dimensions for each species. Average values for fiber length, fiber width, and cell-wall thickness are accompanied by their respective values for coefficient of variation and indicate the dispersion about the mean value in each case. Average lumen width is shown as the difference between average values for fiber width and double cell-wall thickness. The table reveals the wide range of wood and fiber characteristics shown by these 15 species. Specific gravity ranged from 0.29 to 1.16; average fiber length from 985 to 2000 μ; average fiber width from 13.9 to 25.0 μ; average cell-wall thickness from 2.3 to 8.5 μ; and width of lumen from 1.6 to 17.9 μ.

Various ratios, derived from fiber dimensions, commonly used in expressing wood fiber–pulp relationships were calculated and are shown in Table II. A wide range of fiber characteristics is again shown by these data. Slenderness ratio or felting power ranged from 45 to 122; flexibility ratio from 10 to 73; rigidity coefficient from 27 to 90; Runkel ratio from 0.37 to 9.1; Mühlsteph ratio from 47 to 99; and cross-sectional area of cell wall from 11.0 to 42.4 $\times 10^{-5}$ sq. mm.

Pulping Procedure

For pulping, selected plank material was first band-sawn into cross-sectional wafers $^1/_2$-in. long. In the

case of plank stock more than 1-in. thick, the wafer was resawn. The wafers were subsequently converted to chips 1/2-in. long, 1/8-in. thick, and 3/4- to 1-in. wide with an improvised hand splitter. Approximately 10 kg. of chips, expressed on the basis of ovendry wood, were prepared for each species. Chips were thoroughly air-cleaned before pulping.

Pulping of the chips was carried out in the research laboratory of The Crossett Co., Crossett, Ark., using the kraft process. Five different cooks of 2000 g. each were carried out with each species to obtain a distribution of pulp purity ranging about permanganate no. 12. With most species a range of permanganate numbers (P.N.) from approximately 6 to 20 was actually obtained.

Control of the cook was accomplished by varying the amount of active alkali used and, in some cases, by re-cooking if the initial cook proved to be inadequate to obtain the desired level of pulp purity. Sulfidity was held constant at 24%. Cooking time and pressure were the same for nearly all cooks: 1 1/2 hr. to attain a pressure of 100 p.s.i., followed by 1 1/2 hr. during which this pressure was maintained. The pulps were then placed in polyethylene bags and shipped to the Yale School of Forestry for processing and evaluation.

Pulp Processing

A representative pulp sample, equivalent to 360 g. ovendry weight, from each cook was processed in a 1 1/2-lb. Valley beater, following the procedure outlined in TAPPI Standard T 200 m-45. Samples of the pulp slurry were removed for freeness testing, and to obtain stock for handsheet preparation after 0, 5, 15, 25, 45, 65 min. beating, and at longer intervals if necessary, until the pulp had attained an approximate Canadian Standard freeness of 100 ml.

Results of the freeness test for each cook were adjusted to 20°C. by means of the correction table in TAPPI Standard T 227 m-50.

Preparation of Handsheets

The forming of handsheets was carried out according to TAPPI Standard T 205 m-58. Pulp samples for handsheet formation were removed from the beater at the same time intervals previously noted in connection with sampling for freeness testing. Eight sheets were made for each pulp sample. After pressing, the sheets were placed in drying rings and conditioned according to TAPPI Standard T 402 m-49 in a humidity-controlled room maintained at 73°F. and 50% R.H.

Physical and Strength Tests of Handsheets

After conditioning the handsheets, five were selected to represent each pulp condition. The apportioning of sheets among the various tests and the testing procedures themselves were carried out in accordance with TAPPI Standard T 220 m-53. Basis weight, thickness of sheet, tensile strength, bursting strength, tearing strength, and zero-span tensile strength were determined according to the appropriate TAPPI Standards. All tests were carried out in the same humidity-controlled room in which the pulp sheets had been conditioned. Test results were converted to various derived values as shown in TAPPI Standard T 220 m-53.

Zero-span tensile strength (breaking load in lb. on 15 mm. strip) for each pulp condition was divided by basis weight to obtain a measure of intrinsic fiber strength which was called, for the purpose of this study, "fiber quality." For most pulps, no consistent trend of fiber quality with beating time was discernible. Usually somewhat low at zero-minutes beating time, fiber quality was approximately constant over a considerable range of beating time with a tendency to fall off at the longer periods. For most species the "plateau" of maximum fiber quality ranged from 5 to 45 min., extending to 100 min. in a few of the denser species.

Adjustment of Test Results to Permanganate No. 12

Strength values at permanganate no. 12 were estimated by means of simple regression analysis. For each species, values for tear factor, breaking length, and burst factor, were plotted against permanganate number. Separate regressions were determined for each beating interval. From each of these curves the estimated strength value for P.N. 12 at a particular beating time was determined. The same method was used for determining freeness at each beating time for P.N. 12 pulp. From the values obtained in the preceding analysis, regression curves of pulp property versus beating time at P.N. 12 were fitted. Figures 1 to 4 show examples of this procedure for freeness, breaking length, burst factor, and tear factor. From such curves, strength values were taken for each species at

Table III. Pulp Strength Properties and C.S. Freeness for 15 Hardwoods Adjusted to Permanganate No. 12

Species	Fiber quality[a]	Breaking length, m. at 0 min.	Breaking length, m. at 450 ml. C.S.f.	Breaking length, m. at 300 ml. C.S.f.	Burst factor, g./cm.²/g.s.m. at 0 min.	Burst factor, g./cm.²/g.s.m. at 450 ml. C.S.f.	Burst factor, g./cm.²/g.s.m. at 300 ml. C.S.f.	Tear factor, g./g.s.m. at 0 min.	Tear factor, g./g.s.m. at 450 ml. C.S.f.	Tear factor, g./g.s.m. at 300 ml. C.S.f.	Tear factor, g./g.s.m. Maximum	C.S. freeness, ml. at 0 min.	C.S. freeness, ml. at Maximum tear factor
Ceiba	0.603	3575	5509	7001	18.6	32.8	44.3	113	89	70	113	579	579
Copaia	0.736	3307	6511	8786	11.8	34.9	51.8	59	92	81	92	588	460
Simaruba	0.504	4181	4181	6805	23.8	23.8	41.0	80	80	50	80	447	447
Espave	0.564	3809	6467	9505	16.1	37.3	61.9	80	80	63	88	583	540
Laurel blanco	0.656	3483	5560	7628	14.3	30.6	48.3	89	109	99	110	543	425
Red gum	0.791	3061	8518	9810	12.2	42.4	70.2	104	116	102	130	705	640
Roble blanco	0.626	3204	4535	7507	11.5	22.3	46.5	60	84	78	88	492	415
Red oak	0.747	2515	6435	8177	7.1	42.4	58.1	48	110	88	111	676	470
White oak	0.685	2078	4676	6809	5.5	30.8	51.6	43	111	96	113	681	485
Supupira	0.728	1953	6368	7783	2.7	33.7	43.7	37	117	102	117	678	437
Mylady	0.823	2155	6516	8552	4.4	29.1	41.7	43	134	127	135	739	400
Nargusta	0.528	3218	7602	8691	10.9	49.5	52.7	105	108	89	124	644	585
Jarana	0.583	1985	4559	5363	5.5	25.6	33.2	51	88	82	90	643	530
Marishiballi	0.500	1785	3526	4370	2.0	12.8	18.0	32	57	57	59	741	385
Bannia	0.532	1493	4922	5680	1.7	18.6	26.3	23	62	65	66	684	330

[a] Zero-span tensile strength/basis weight.

Table IV. Multiple-Regression Equations for Each Pulp Property[a]

Equation No.	Variables	Items[b]	Coefficients		Level of significance t	Level of significance %	Coefficient of determination r^2	Level of significance % [c]
			Freeness at Zero-Minutes					
		Log constant a		3.60901				
1	x_1	Log $1/(l + D)$	b_1	−0.20278	−1.916	10	0.882	1
	x_2	Log $1/2w$	b_2	−0.24899	−4.450	1		
	x_3	Log $1/SG$	b_3	−0.20131	−2.141	10		
			Breaking Length at Zero-Minutes					
		Log constant a		1.16288				
2	x_1	Log l	b_1	0.24829	2.323	5	0.869	1
	x_2	Log $1/D$	b_2	0.49308	2.328	5		
	x_3	Log SG	b_3	−0.37380	−1.944	10		
			Burst Factor at Zero-Minutes					
		Log constant a		0.39657				
3	x_1	Log l	b_1	0.52516	1.787	10	0.852	1
	x_2	Log $1/D$	b_2	1.35803	2.333	5		
	x_3	Log SG	b_3	−1.17017	−2.213	5		
			Tear Factor at Zero-Minutes					
		Log constant a		−5.24661				
4	x_1	Log L	b_1	1.89864	6.888	1	0.902	1
	x_2	Log $1/2w$	b_2	0.92442	4.849	1		
	x_3	Log l	b_3	0.12065	1.430	20		
			Breaking Length at C.S f. 450 ml.					
		Log constant a		−0.42338				
5	x_1	Log l/D	b_1	0.35015	2.271	5	0.579	5
	x_2	Log FD	b_2	0.08397	1.851	10		
	x_3	Log L	b_3	0.37198	2.081	10		
	x_4	Log SG	b_4	0.24785	1.433	20		
			Breaking Length at C.S.f. 450 ml.					
		Log constant a		0.48474				
6	x_1	Log l/D	b_1	0.18977	1.990	10	0.531	5
	x_2	Log FD	b_2	0.08731	1.792	10		
	x_3	Log FQ	b_3	0.38889	1.051	N.S.		
			Burst Factor at C.S.f. 450 ml.					
		Log constant a		−2.78620				
7	x_1	Log l/D	b_1	0.62587	2.998	5	0.686	1
	x_2	Log FD	b_2	0.07385	1.202	N.S.		
	x_3	Log L	b_3	0.85843	2.393	5		
	x_4	Log SG	b_4	0.45790	1.300	N.S.		
			Burst Factor at C.S.f. 450 ml.					
		Log constant a		−0.33522				
8	x_1	Log l/D	b_1	0.36376	2.428	5	0.529	5
	x_2	Log FD	b_2	0.10867	1.420	20		
	x_3	Log FQ	b_3	0.51036	0.878	N.S.		
			Tear Factor at C.S.f. 450 ml.					
		Log constant a		−0.91944				
9	x_1	Log L	b_1	0.34032	1.913	10	0.709	1
	x_2	Log FQ	b_2	1.00934	4.345	1		
			Breaking Length at C.S.f. 300 ml.					
		Log constant a		0.00364				
10	x_1	Log l/D	b_1	0.32236	4.138	1	0.784	1
	x_2	Log FD	b_2	0.34265	1.924	10		
	x_3	Log FQ	b_3	0.28323	1.109	N.S.		
			Burst Factor at C.S.f. 300 ml.					
		Log constant a		−0.90973				
11	x_1	Log l/D	b_1	0.47234	3.788	1	0.767	1
	x_2	Log FD	b_2	0.39203	1.375	20		
	x_3	Log FQ	b_3	0.46939	1.149	N.S.		
			Tear Factor at C.S.f. 300 ml.					
		Log constant a		−1.08948				
12	x_1	Log L	b_1	0.29872	1.739	20	0.752	1
	x_2	Log FQ	b_2	1.14204	5.092	1		
			Maximum Tear Factor					
		Log constant a		−1.16388				
13	x_1	Log L	b_1	0.52282	2.860	5	0.700	1
	x_2	Log FQ	b_2	0.83835	3.511	1		

[a] Equation type: $\log y = a + b_1x_1 + b_2x_2 + \ldots$ where y = pulp property desired.
[b] Code: $1/(l + D) \times 1000$; $(1/2w \times 100)$; $(1/SG \times 10)$; $(SG \times 10)$; $(1/D \times 100)$: $(FQ \times 100)$; $(l/D \times 100)$.
[c] G. W. Snedecor, Statistical Methods, Iowa State College Press, Ames, Iowa, 1946, Table 13.6.

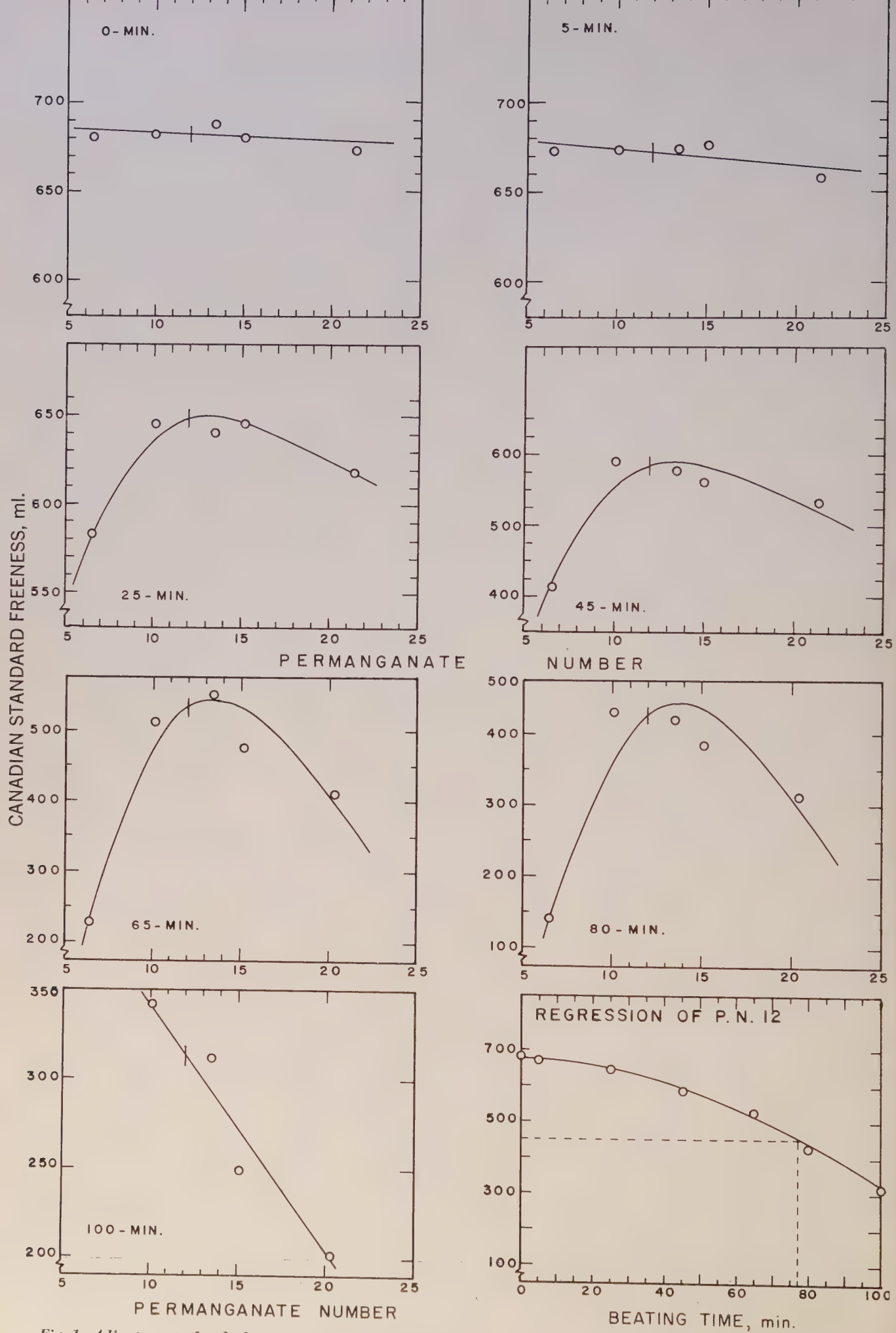

Fig. 1. Adjustment of pulp freeness to permanganate no. 12 and relation of adjusted freeness to beating time

Sample data for supupira.

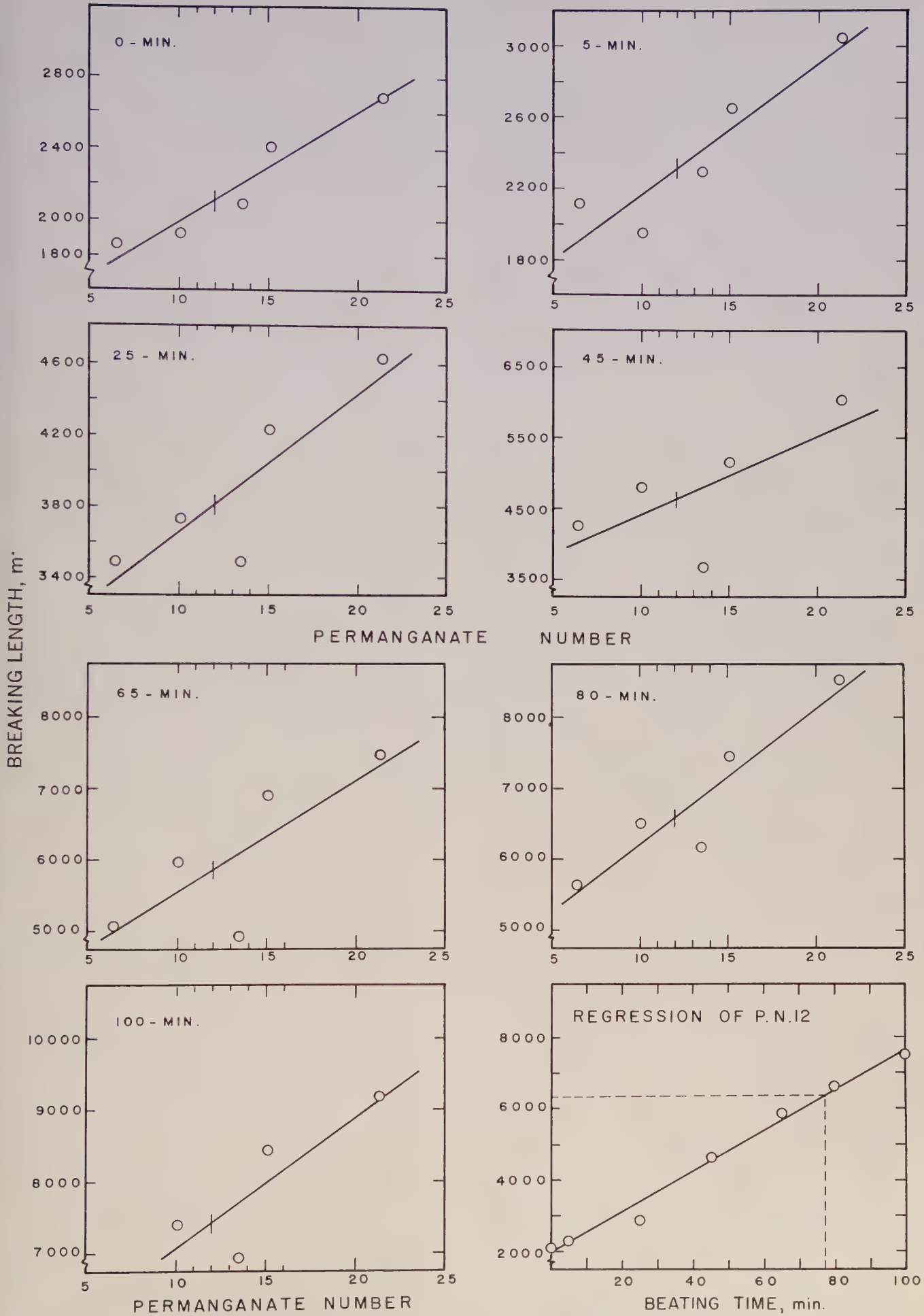

Fig. 2. Adjustment of breaking length to permanganate no. 12 and relation of adjusted breaking length to beating time

Sample data for supupira.

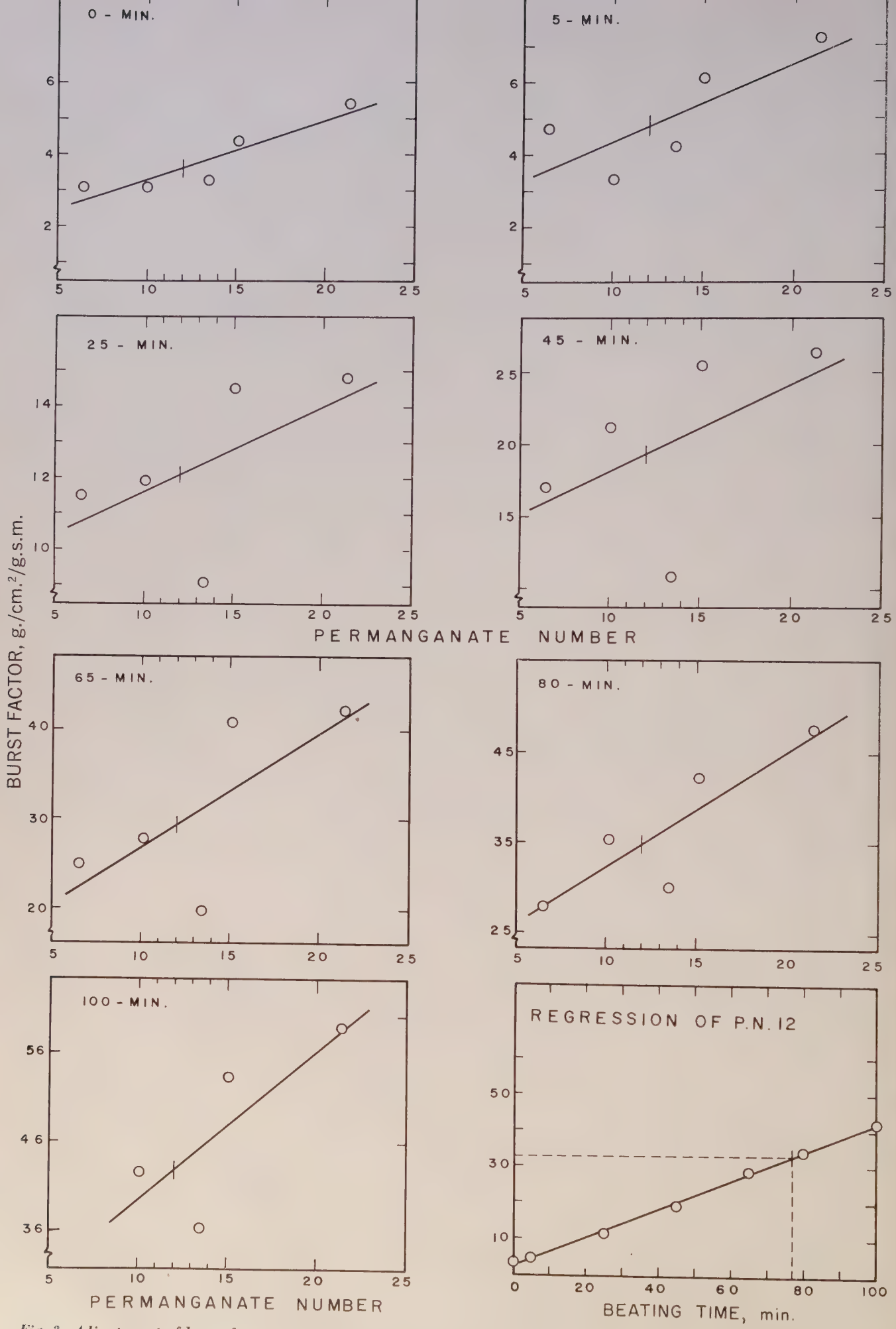

Fig. 3. Adjustment of burst factor to permanganate no. 12 and relation of adjusted burst factor to beating time

Sample data for supupira.

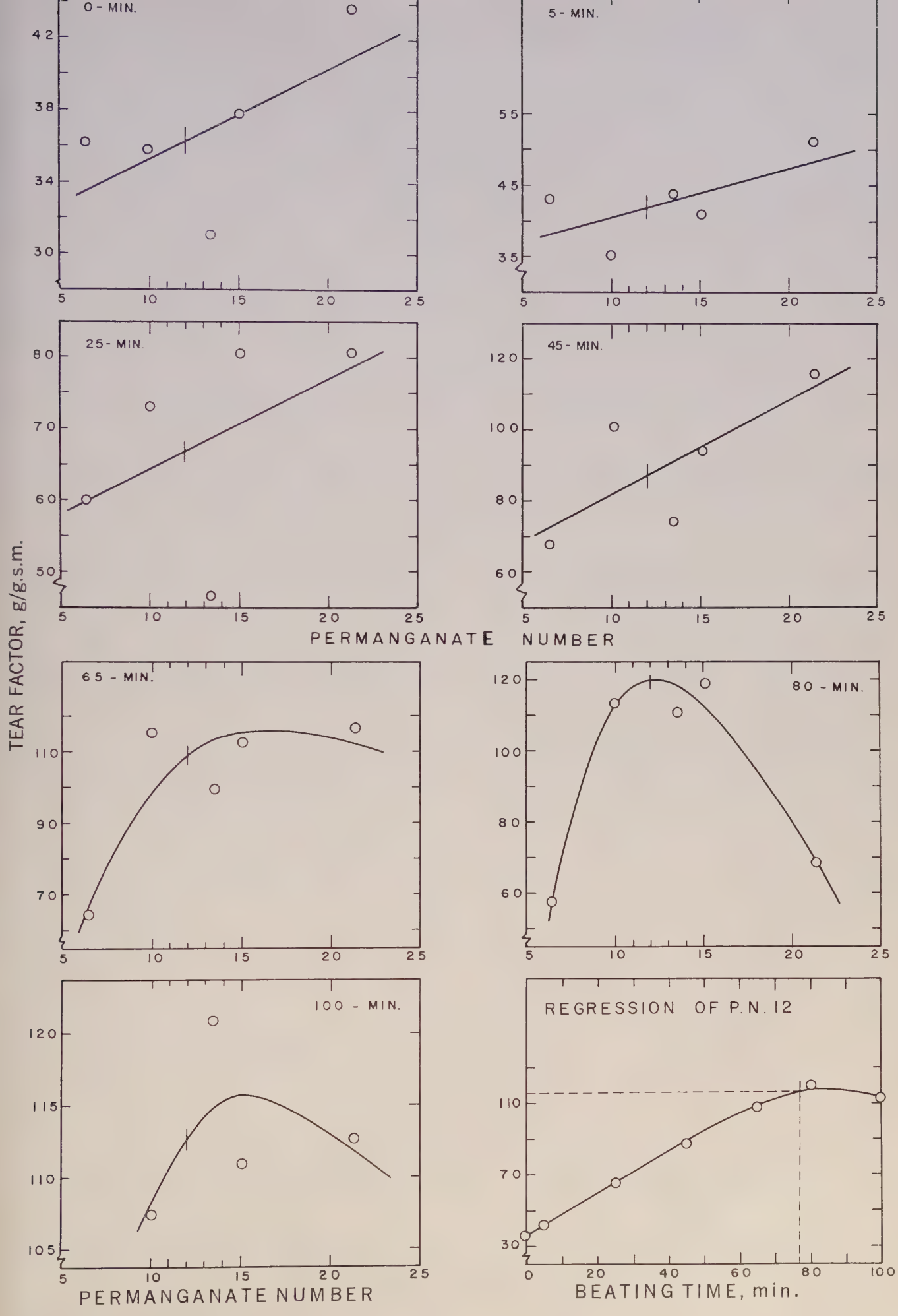

Fig. 4. Adjustment of tear factor to permanganate no. 12 and relation of adjusted tear factor to beating time

Sample data for supupira.

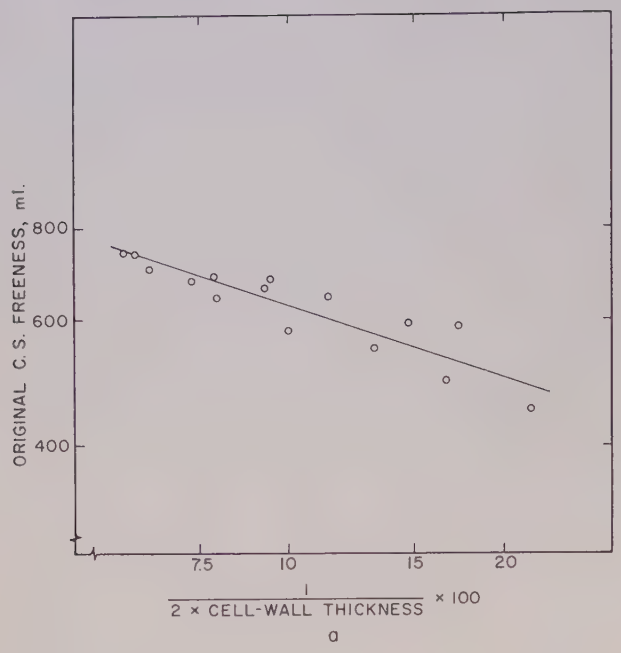

Fig. 5a. Simple regression of original pulp freeness on double cell-wall thickness (2w)

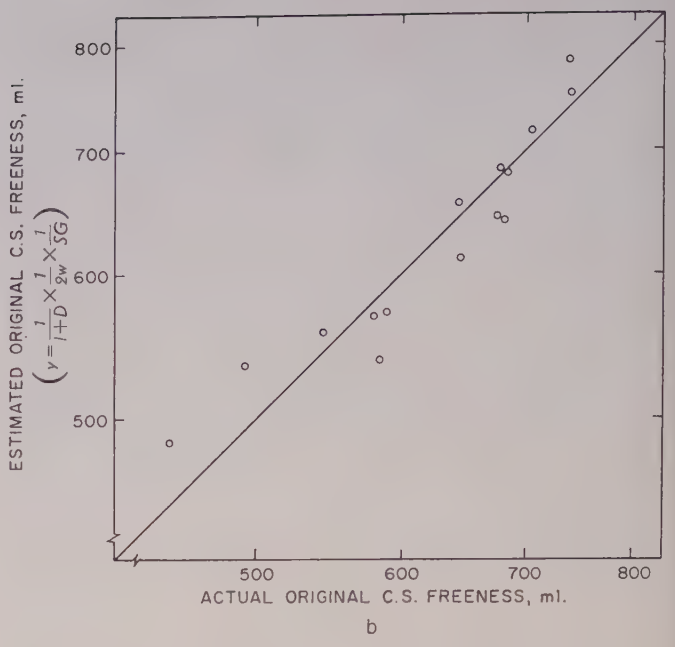

Fig. 5b. Multiple-regression estimates plotted against experimental values for original freeness

Variables in Fig. 5b: reciprocal of lumen width and fiber diameter $[(1)/(l + D)]$; reciprocal of double wallth ickness $(1/2w)$; reciprocal of specific gravity $(1/SG)$.

zero minutes, and at beating times corresponding to 450 and 300 C.S. freeness. Maximum tear factor was also read from the regression curve for this property at P.N. 12.

Fiber quality at P.N. 12 was determined for each species from the regression with permanganate number as has been described for the adjustment of other properties.

RELATIONSHIPS BETWEEN WOOD FIBER CHARACTERISTICS AND PULP-SHEET PROPERTIES

Table III shows strength values determined for each species at permanganate no. 12, prior to beating as well as after various degrees of beating. These values were first trial-plotted against various combinations of fiber dimensions and wood properties in an attempt to detect possible correlations. When relationships appeared to be promising the data were prepared for analysis by means of an IBM 650 computer which was programmed to determine the proportion of total variance accounted for by each independent variable and by all possible combinations of the variables submitted for test. The best practical combination of

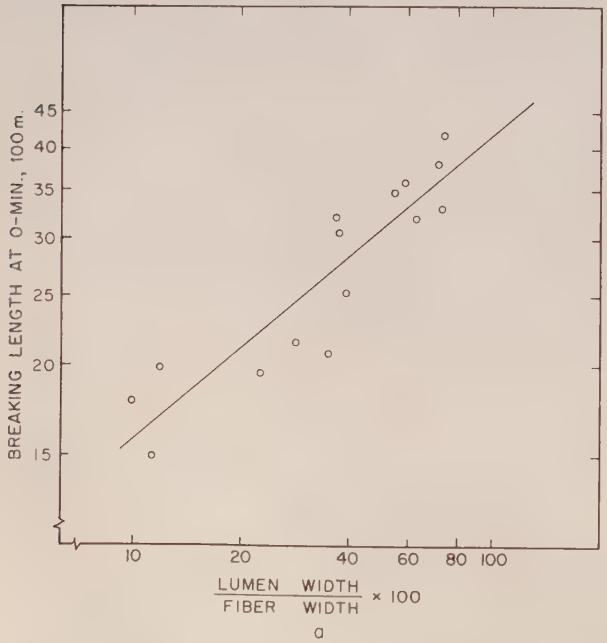

Fig. 6a. Simple regression of breaking length of unbeaten pulps on flexibility ratio l/D

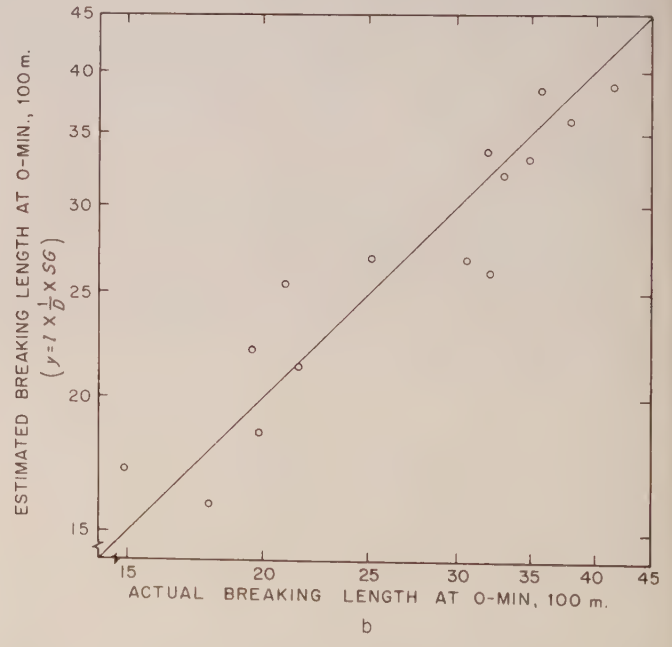

Fig. 6b. Multiple-regression estimates plotted against experimental values for breaking length of unbeaten pulps

Variables in Fig. 6b: lumen width l, reciprocal of fiber diameter $1/D$, specific gravity of wood SG.

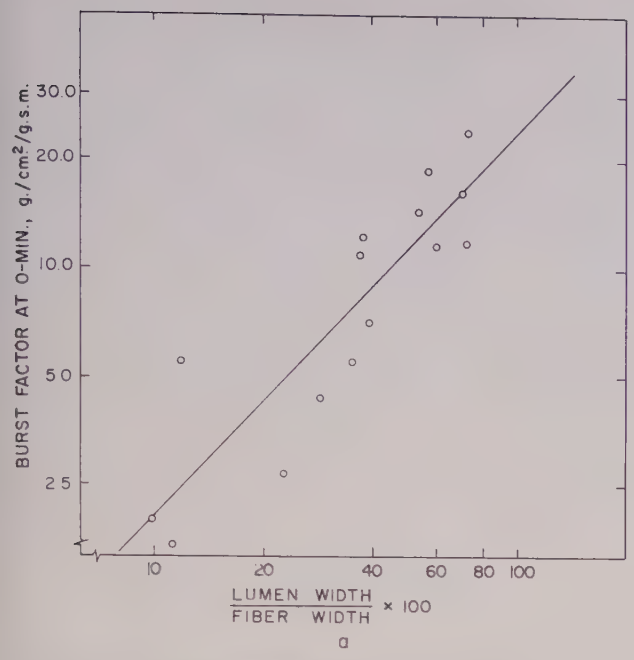

Fig. 7a. Simple regression of burst factor of unbeaten pulps on flexibility ratio l/D

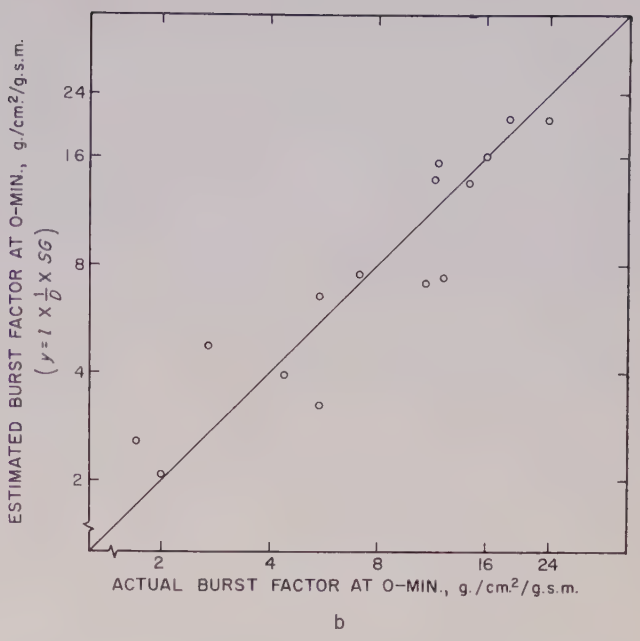

Fig. 7b. Multiple-regression estimates plotted against experimental values for burst factor of unbeaten pulps

Variables in Fig. 7b: lumen width l, reciprocal of fiber diameter $1/D$, specific gravity of wood SG.

variables, i.e., the simplest combination that accounted for the largest (or close to the largest) percentage of total variance, was then employed in the final determination of a multiple-regression equation for each pulp property. Fig. 5 to 15 and Table IV show the results of this analysis.

In preparing data on fiber characteristics (Table I and II) and pulp properties at P.N. 12 (Table III) for analysis, all values were reduced to logarithms. Consequently, in the discussion that follows all references to pulp properties or fiber dimensions (or ratios of such dimensions) are to the logarithm of the variable and all relationships shown in the graphs are plotted on a logarithmic scale.

Pulp Properties at Zero-Minutes Beating Time

The original freeness of these pulps increased with increasing cell-wall thickness. When plotted as log freeness versus log $1/2w$, where $2w$ = double cell-wall thickness, the relationship appears as shown in Fig. 5a. The simple regression accounted for 83% of the total variation between species in freeness ranging from approximately 450 to 740 ml. In multiple-regression analysis, the inclusion of log $1/SG$, where SG = specific gravity of the original wood, as a component of the independent variable had no appreciable effect, but the further addition of log $1/(l + D)$, where l = lumen width and D = fiber diameter, increased the percentage of accountable variation to 88 at the 1% level of signifi-

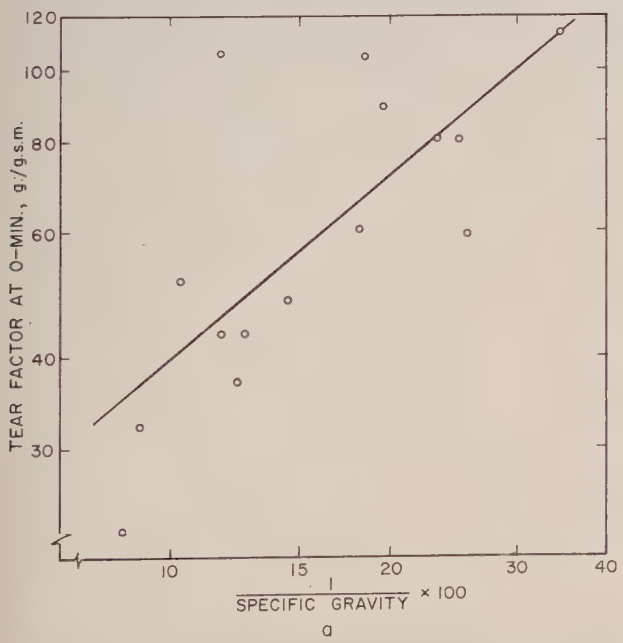

Fig. 8a. Simple regression of tear factor of unbeaten pulps on reciprocal of specific gravity of wood 1/SG

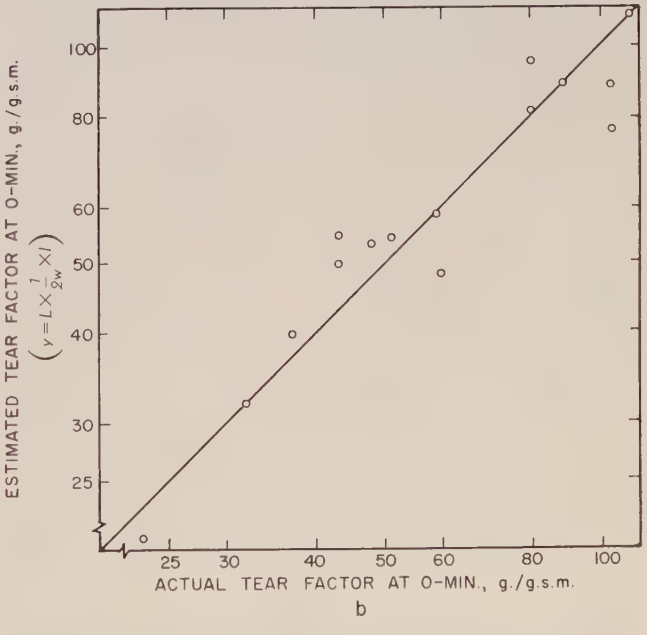

Fig. 8b. Multiple-regression estimates plotted against experimental values for tear factor of unbeaten pulps

Variables in Fig. 8b: fiber length L, reciprocal of double cell-wall thickness $1/2w$, lumen width l.

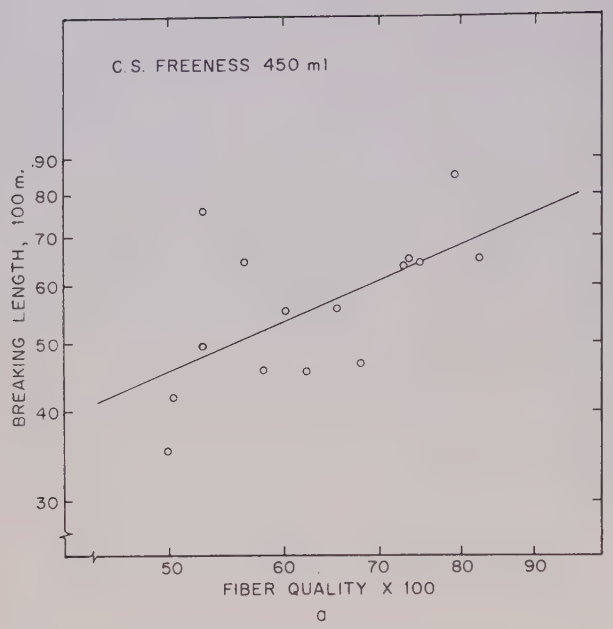

Fig. 9a. Simple regression of breaking length at a C.S. freeness of 450 ml. on fiber quality FQ

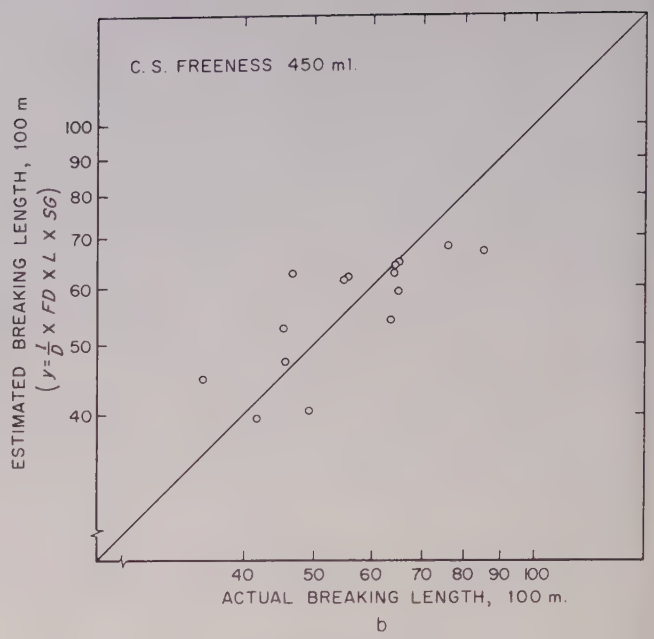

Fig. 9b. Multiple-regression estimates plotted against experimental values for breaking length at a C.S. freeness of 450 ml.

Variables in Fig. 9b: flexibility ratio l/D, freeness decrement FD, fiber length L, specific gravity of wood SG.

cance. Constants and coefficients of the multiple-regression equation of the type $Y = a + b_1x_1 + b_2x_2 + \ldots$ together with the significance levels of the individual components are included in Table IV. Estimates for each species derived from the multiple-regression equation are plotted against corresponding experimental values in Fig. 5b.

The tensile strength of the unbeaten pulps was closely related to flexibility ratio, i.e., lumen width/fiber width l/D. Plotted as log (breaking length) versus log l/D, the relationship appears as shown in Fig. 6a. The simple regression accounted for 82% of the total variation over a range of breaking length from 1490 to 4180 m. Multiple-regression analysis of the relationship log (breaking length) versus log l + log $1/D$ + log SG accounted for 87% of total variation, significant at the 1% level. Constants and coefficients of the multiple-regression equation for this relationship are included in Table IV. Estimates are plotted against actual values in Fig. 6b. The limited scatter about the 45° line on the graph indicates the extent to which the relationship accounts for breaking length of the individual species tested.

Bursting strength in the unbeaten condition closely paralleled breaking length in its relationships with fiber and wood characteristics. The simple regression of burst factor with flexibility ratio, shown graphically in Fig. 7a, accounted for 78% of total variation over a

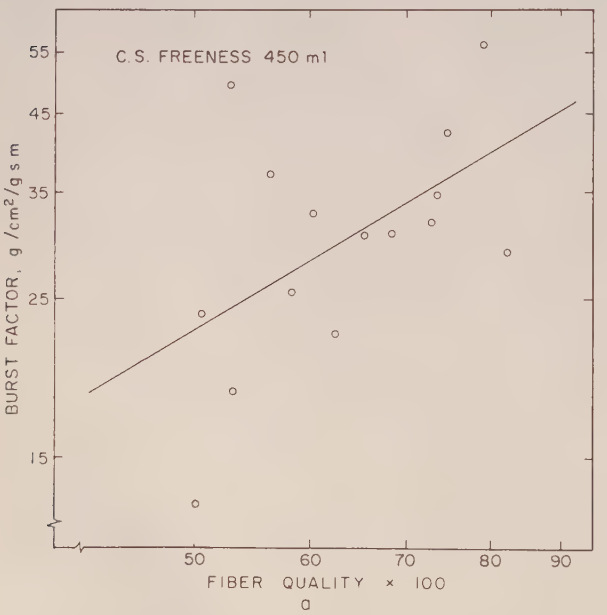

Fig. 10a. Simple regression of burst factor at a C.S. freeness of 450 ml. on fiber quality FQ

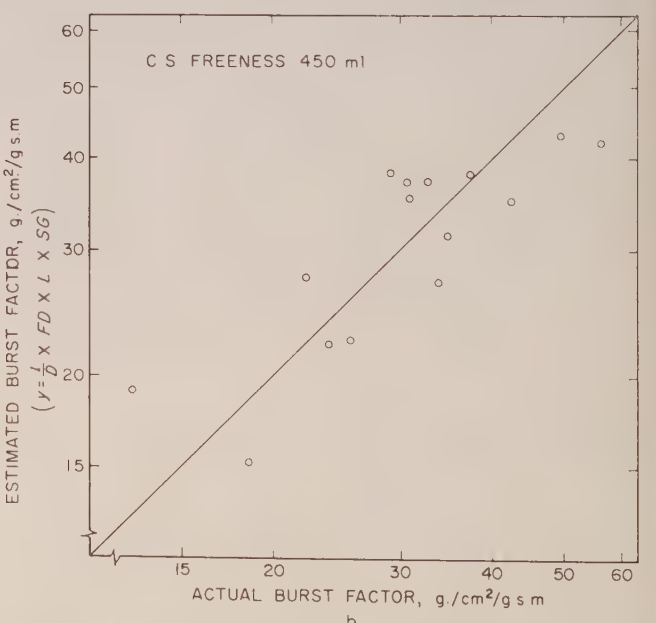

Fig. 10b. Multiple-regression estimates plotted against experimental values for burst factor at a C.S. freeness of 450 ml.

Variables in Fig. 10b: flexibility ratio l/D, freeness decrement FD, fiber length L, specific gravity of wood SG.

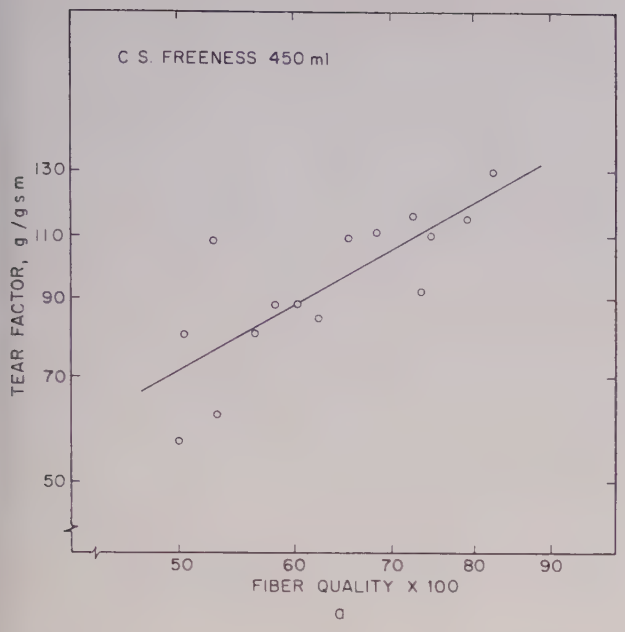

Fig. 11a. Simple regression of tear factor at a C.S. freeness of 450 ml. on fiber quality FQ

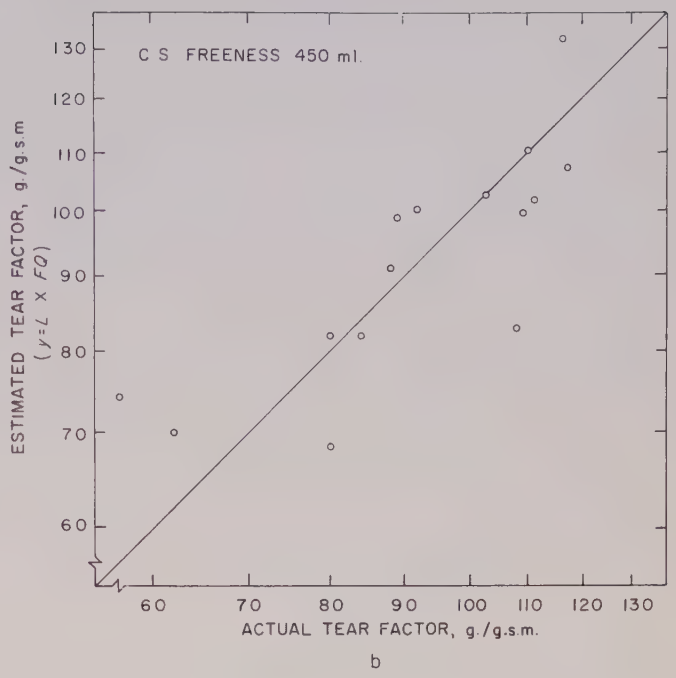

Fig. 11b. Multiple-regression estimates plotted against experimental values for tear factor at a C.S. freeness of 450 ml.

Variables in Fig. 11b: fiber length L, fiber quality FQ.

range extending from 1.7 to 24. In multiple regression l, $1/D$, and SG (see Table IV), handled as described for breaking length, accounted for 85% of total variation in burst factor. The regression was significant at the 1% level. Equation-based estimates versus experimental values for burst factor for individual species are plotted in Fig. 7b.

Tearing strength in the unbeaten condition, expressed as tear factor, ranged from approximately 25 to 115. Figure 8a shows that, plotted against $1/SG$, the simple regression accounted for 54% of total variation. Multiple regression involving log values for $1/2w$, fiber length L, and lumen width l, shown in Table IV, accounted for 90% of total variation and was significant at 1%. Estimates from the multiple regression are plotted against actual tear factor in Fig. 8b.

Pulp Properties at C.S. Freeness of 450 ml.

Unlike the relationship for unbeaten pulp, tensile strength of pulp beaten to a C.S. freeness of 450 ml. cannot be explained by a simple regression with flexibility ratio. At this level of freeness, breaking length ranged from approximately 3530 to 8520 m. Flexibility ratio l/D alone accounted for only 12% of the

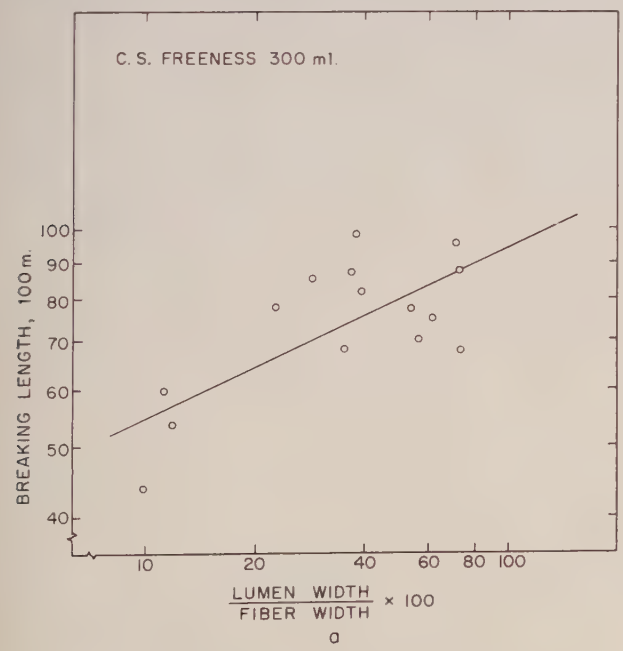

Fig. 12a. Simple regression of breaking length at a C.S. freeness of 300 ml. on flexibility ratio l/D

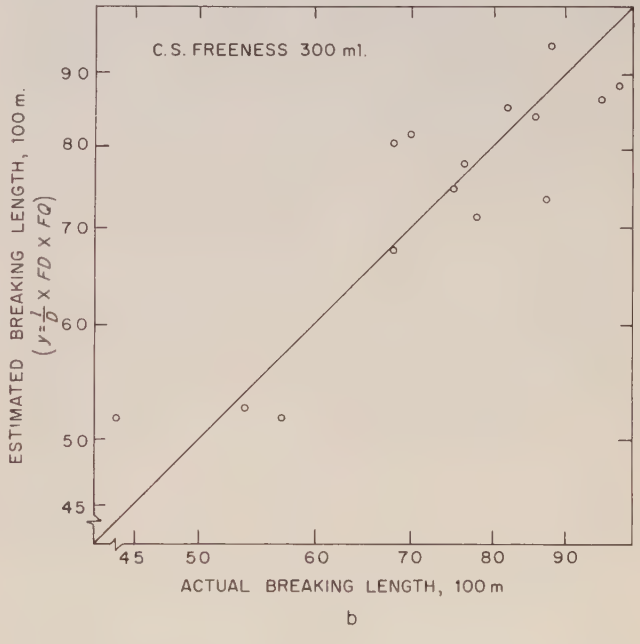

Fig. 12b. Multiple-regression estimates plotted against experimental values for breaking length at a C.S. freeness of 300 ml.

Variables in Fig. 12b: flexibility ratio l/D, freeness decrement FD, fiber quality FQ.

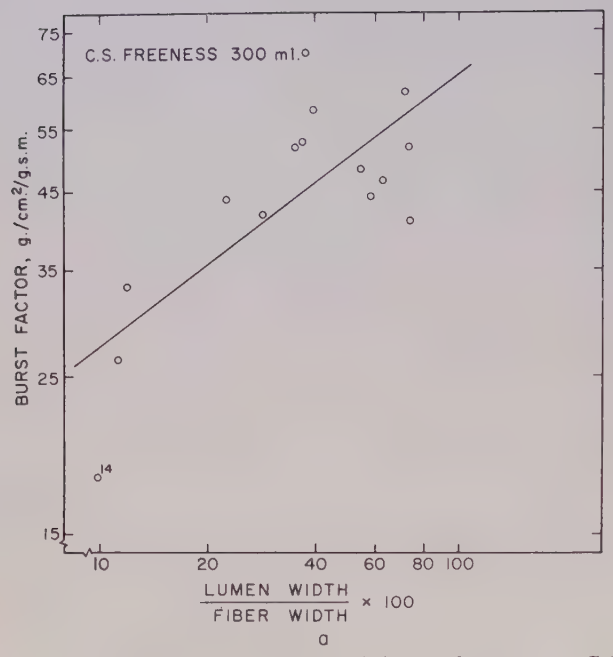

Fig. 13a. Simple regression of burst factor at a C.S. freeness of 300 ml. on flexibility ratio l/D

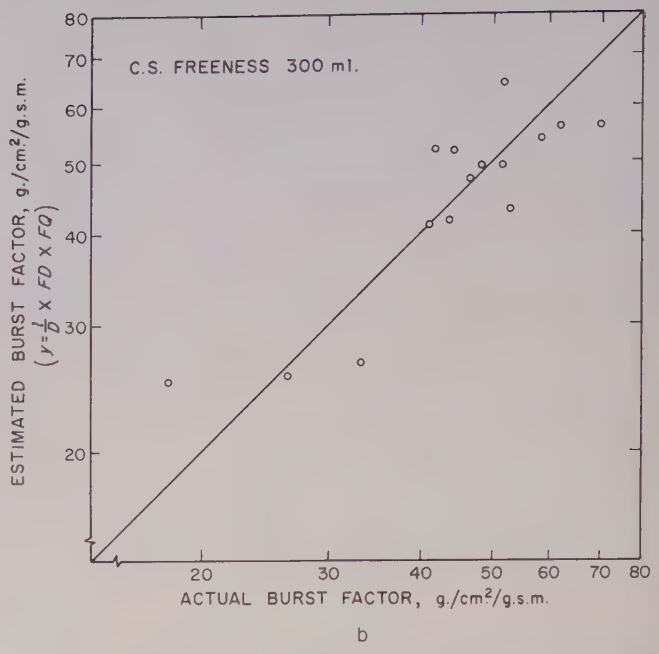

Fig. 13b. Multiple-regression estimates plotted against experimental values for burst factor at a C.S. freeness of 300 ml.

Variables in Fig. 13b: flexibility ratio l/D, freeness decrement FD, fiber quality FQ.

total logarithmic variation between species. The most significant single factor affecting breaking length appears to be fiber quality (FQ). Figure 9a shows that this relationship is far from adequate, accounting for only 34% of total variation in breaking length. Multivariate analysis also left a substantial amount of unaccountable variation at a C.S. freeness of 450 ml. Multiple regression involving log l/D + log (freeness decrement) (FD)* + log L + log SG accounted for 58% of total variation and was significant at the 5% level. Figure 9b gives equation-based estimates versus experimental values for breaking length at a C.S. freeness of 450 ml. Table IV gives constants and coefficients of the multiple-regression equation. An alternative choice of variables in multiple regression involving l/D, FD, and FQ is also included in Table IV. These three variables accounted for 53% of total variation with similar significance.

Bursting strength at a C.S. freeness of 450 ml. showed similar relationships to those just described for breaking length. The simple correlation with flexibility ratio l/D accounted for only 26% of total variation in burst factor ranging from approximately 13 to 50. The relationship with fiber quality, shown in Fig. 10a, was only slightly better, accounting for 28% of total variation. Multiple regression involving log

* The term freeness decrement used in these multiple-regression relationships at a C.S. freeness of 450 ml. refers to the difference between original freeness (see Table III) and freeness of 450 ml.

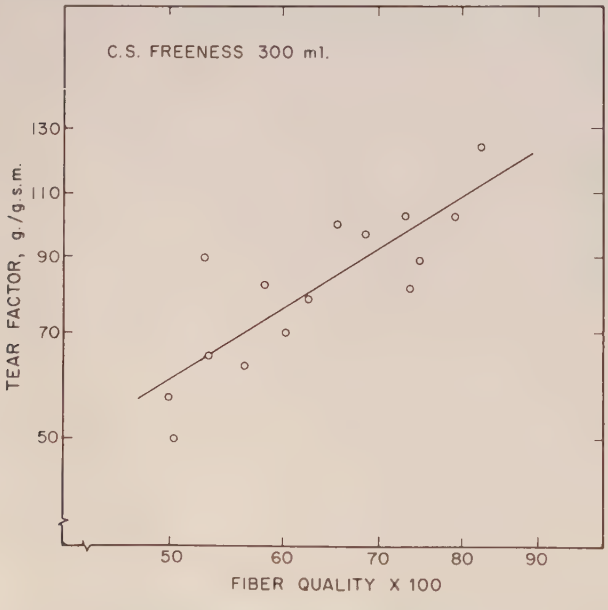

Fig. 14a. Simple regression of tear factor at a C.S. freeness of 300 ml. on fiber quality FQ

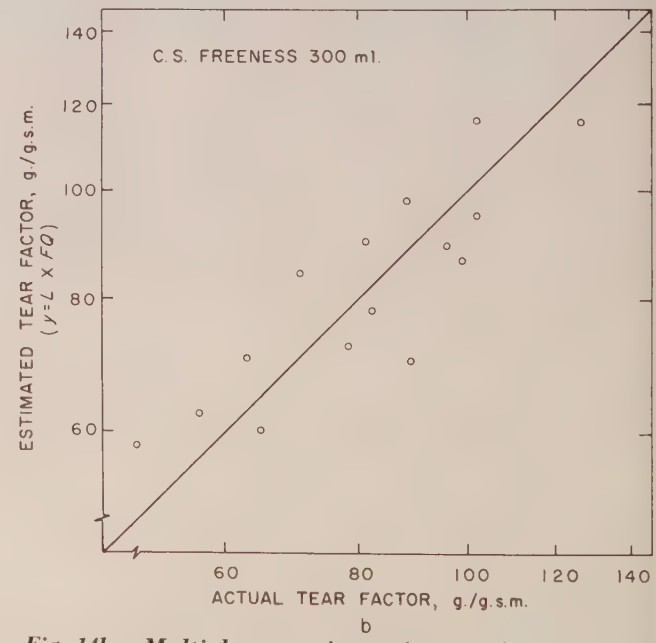

Fig. 14b. Multiple-regression estimates plotted against experimental values for tear factor at a C.S. freeness of 300 ml.

Variables in Fig. 14b.: fiber length L, fiber quality FQ.

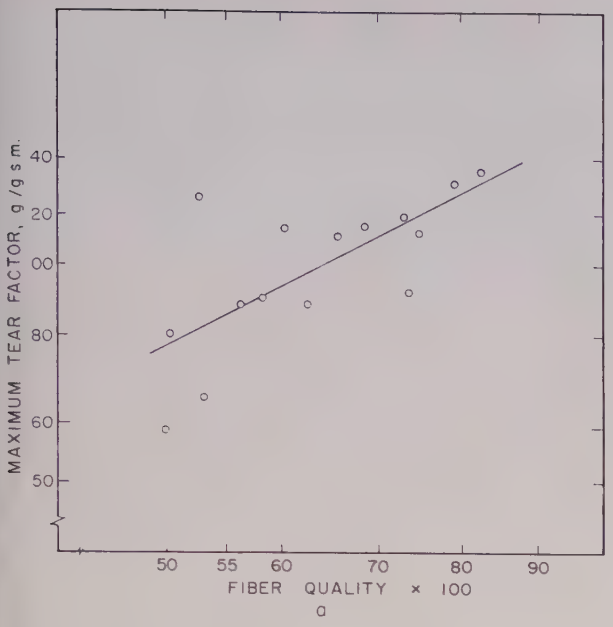

Fig. 15a. Simple regression of maximum tear factor on fiber quality FQ

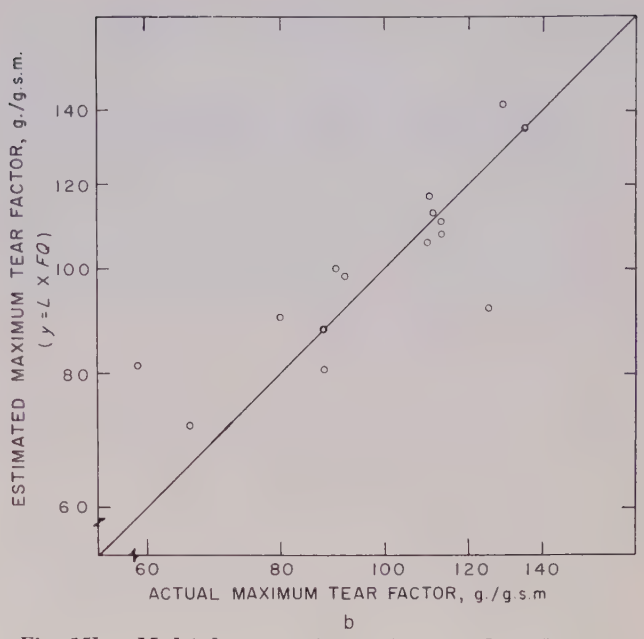

Fig. 15b. Multiple-regression estimates plotted against experimental values for maximum tear factor

Variables in Fig. 15b: fiber length L, fiber quality FQ.

values for flexibility ratio, freeness decrement, fiber length, and specific gravity of wood (see Table IV) accounted for 69% of the total variation in burst factor at a C.S. freeness of 450 ml. and was significant at 1%. In Fig. 10b estimates derived from this equation are plotted against corresponding experimental values and indicate the extent of individual species deviation from this relationship. An alternative choice of variables involving l/D, FD, and FQ achieved significance at 5% (see Table IV) but accounted for only 53% of total variation.

Contrary to expectations based on a review of the literature, an initial plotting of tear strength at a C.S. freeness of 450 ml. versus felting power L/D failed to show any well defined trend. In multiple regression, $\log L + \log 1/D$ accounted for only 26% of total logarithmic variation in tear factor. By simple regression analysis it was found that fiber length L alone accounted for 25% of the total. Figure 11a shows that a considerably better relationship was that between tear factor and fiber quality FQ. This relationship accounted for 62% of the total variation in tear factor ranging from approximately 60 to 135. The multiple-regression equation (see Table IV) for the relationship log (tear factor) versus $\log L + \log FQ$ accounted for 71% of the total variation and was significant at 1%. Estimated values for tear factor at a C.S. freeness of 450 ml. from this equation are plotted against actual test values in Fig. 11b.

Pulp Properties at C.S. Freeness of 300 ml.

Values for breaking length at a C.S. freeness of 300 ml. were found to be related to flexibility ratio l/D, as shown by the simple correlation in Fig. 12a. Over a range in breaking length from 4370 to 9810 m., flexibility ratio alone accounted for 51% of the total variation shown between individual species. Multiple-regression analysis (see Table IV) of data in log form involving three factors: l/D, FD,† and FQ accounted for 78% of total variation in breaking length at a C.S. freeness of 300 ml. The relationship was significant at 1%. Equation-based estimates for breaking length are plotted against actual test values in Fig. 12b.

Burst factor at a C.S. freeness of 300 ml. exhibited similar relationships to fiber characteristics. Figure 13a shows that simple regression with flexibility ratio accounted for 57% of total variation in burst factor, which ranged from 18 to 70. Multiple-regression analysis involving logarithmic values of l/D, FD, and FQ (see Table IV) accounted for 77% of the total variation in burst factor at this level of freeness. In Fig. 13b estimated values from the multiple-regression equation are plotted against actual values. The relationship was found to be significant at 1%.

As was previously shown for pulp at a C.S. freeness of 450 ml., variation in tearing strength at C.S. freeness of 300 ml. showed no trend with felting power L/D. Multiple regression involving L and $1/D$ accounted for only 22% of total logarithmic variation. Fiber length alone also accounted for 22% of the total. The best simple regression was that shown in Fig. 14a relating tear factor to fiber quality. This relationship accounted for 69% of the total variation in tear factor ranging from approximately 50 to 130. Inclusion of fiber length L with fiber quality FQ in a multiple regression accounted for 75% of the total variation in tear factor. The relationship was significant at 1%. Equation coefficients and constants are given in Table IV. In Fig. 14b equation-based estimates are plotted against actual values.

Maximum Tearing Strength

Considering all 15 species at P.N. 12, maximum tear factor, which was developed at C.S. freeness levels as high as 640 ml. and as low as 330 ml. in the case of individual species, ranged from approximately 60 to 135. Again, as at C.S. freeness levels of 450 and 300 ml., variation could not be explained satisfactorily by felting power L/D. In multiple-regression analysis

† At a C.S. freeness of 300 ml., FD refers to the difference between original freeness (see Table III) and a freeness of 300 ml.

L and $1/D$ accounted for only 41% of total logarithmic variation. Fiber length L alone accounted for 39% of the total. The best simple correlation with maximum tear factor was obtained using fiber quality FQ as the independent variable. This relationship, shown in Fig. 15a, accounted for 50% of total variation in maximum tear factor. Multiple regression (see Table IV) relating log (maximum tear factor) to log L + log FQ accounted for 70% of the total variation and was significant at the 1% level. In Fig. 15b estimated values from the multiple-regression equation are plotted against actual values for each species.

CONCLUSIONS

To a very substantial degree, hardwood pulp properties are related to the morphological characteristics of fiber, intrinsic fiber strength, and specific gravity of the wood. Quantitative relationships have been established between individual fiber characteristics, or combinations of characteristics, and specific pulp properties for a broad range of hardwood fibers in kraft pulps. Most of these relationships have been shown to be statistically significant at the 1% level. Since the regressions were selected from among a larger number screened for each pulp property, the statistical significance levels shown may not be sufficiently conservative and the probability of random error may be somewhat greater than that indicated.

The results of this study appear to justify the following conclusions:

Pulp freeness prior to beating is related primarily to cell-wall thickness, increasing as wall thickness increases (Fig. 5a).

Tensile and bursting strengths of unbeaten pulp are favorably influenced by increasing flexibility ratio l/D, as shown in Fig. 6a and 7a. Analyzed in terms of the influence of individual factors in multiple correlation, breaking length and burst factor are adversely affected by increasing fiber diameter D and specific gravity of wood SG, and improved by increasing lumen width l (See Table IV, equations (2) and (3). These relationships are consistent with sheet behavior in which strength is controlled by fiber-to-fiber bonding and favored by improved contact surface area.

As beating progresses and freeness decreases, flexibility ratio l/D alone becomes quite ineffective in accounting for pulp tensile and bursting strength properties. At a C.S. freeness of 450 ml., these strength properties may be expressed in terms of the combined influence of FQ, l/D, and FD, increasing as each of these variables increases (See Table IV, equations (6) and (8). Thus intrinsic fiber strength and change from original freeness (itself related positively to cell-wal thickness) are involved together with flexibility ratio in accounting for pulpsheet strength. At this condition sheet strength appears to be influenced by both fiber-to-fiber bonding and individual fiber strength. However, nearly half of the total variation at a C.S. freeness of 450 ml. remains unaccounted for.

The situation is somewhat clarified at a C.S. freeness of 300 ml. where the same three factors prevail and less than 25% of the total variation remains unaccounted for (See Table IV, equations (10) and (11)).

Tearing strength of unbeaten pulps increases with increasing reciprocal of specific gravity of wood ($1/SG$), as shown in Fig. 8a. A better relationship is shown by the combination of factors in which tear factor increases with increasing fiber length L and increasing lumen width l and decreases with increasing cell-wall thickness w (See Table IV, equation (4)). This relationship suggests that in the unbeaten condition tearing strength is heavily influenced by fiber-to-fiber bonding.

Tear factor at various stages of beating failed to show the anticipated simple relationship with felting power L/D or fiber length L. Intrinsic fiber strength, expressed as fiber quality FQ, was the best single variable showing a relationship to tear factor (Figs. 11a, 14a, and 15a), accounting for one-half to two-thirds of the total variation in tear at C.S. freenesses of 450, and 300 ml., and in maximum tear regardless of the level of freeness at which tearing strength attained its maximum. A combination of two variables, fiber length L and fiber quality FQ, both positively related to tear factor, accounted for 70 to 75% of the total variation at all three conditions of freeness. (See Table IV, equations (9), (12), and (13).

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A Precision Technique for Measurement of Coating Thickness and Weight

HAYDN H. MURRAY and WILLIAM D. JOHNS

A method for determining precisely the thickness and weight of inorganic coating layers has been developed using an x-ray absorption technique. The mass absorption coefficient was calculated for kaolins and by substitution in proper formula, the film thickness was determined. Coated sheets of variable basis weight, utilizing different adhesives and coat weights, were used. The method is rapid and precise and coating thicknesses can be determined with an accuracy of ±0.5 μ. The method can be used to determine the thickness or coat weight of any inorganic coating material and it is believed that the method can be adapted for production control.

AN ACCURATE method for determining coat weights is time consuming and tedious. There is need for a rapid and precise method for determining coat weight which possibly can be adapted for use on the machine coaters. This need of rapidly determining coat weight was first brought to the attention of H. H. Murray by Rolf Edholm of the General Electric X-Ray Co., Milwaukee, Wis.

Two methods, using x-rays, were tried. The first, which involved diffraction from the clay minerals in the coating layer, was unsuccessful because of variations in the orientation of the flat clay particles on the base sheet (Fig. 1). Kraske (*1*) has recently demonstrated the application of x-ray diffraction to pigment orientation and film structure in coatings. The second method, using x-ray absorption, proved to be a rapid and precise method. This latter technique will be discussed in detail in this paper.

METHODS AND MATERIALS

X-ray absorption follows the same laws that govern the passage of light through a transparent medium. The behavior of light is expressed by the following exponential relationship:

$$I = I_0 e^{-ux} \qquad (1)$$

where

I_0 = light intensity before passing through a medium
I = light intensity after passing through a medium
x = thickness of medium, cm
u = linear absorption coefficient, cm.$^{-1}$

The term u is a proportionality constant which is dependent upon the nature (composition and state) of the absorbing medium and the wavelength of the light under consideration (in this case x-radiation with wavelengths the order of 1 A.).

A more convenient form of the absorption coefficient is the mass absorption coefficient u/ρ, which is independent of the physical state of the medium. Since u/ρ can be calculated, a more useful form of the absorption relationship is:

$$I = I_0 e^{-u/\rho \, x\rho} \qquad (2)$$

where

u/ρ = mass absorption coefficient of the medium, cm.^{2}/g.
ρ = density of the absorbing medium, g./cc.

Calculation of Mass Absorption Coefficients

I/I_0 can be determined experimentally as will be described below. The mass absorption coefficient u/ρ can be calculated if the composition of the absorbing medium is known. The coefficients for most of the common elements are known for those wavelengths most commonly available in commercial-type x-ray tubes. The mass absorption coefficients for the elements common to kaolin, for CuK_α, (λ = 1.54 A.) x-radiation are given in Table I. More complete tables including some of the more minor elements are given in the "Handbook of Chemistry and Physics" (*2*).

To determine the mass absorption coefficients for compounds, it is necessary only to sum the relative contributions of the constituent elements as follows:

$$u/\rho_{\text{compound}} = w_1(u/\rho_1) + w_2(u/\rho_2) + w_n(u/\rho_n) \qquad (3)$$

where w_1, w_2, w_n are the weight fractions of each element in the compound, and (u/ρ_1), (u/ρ_2), (u/ρ_n) are the mass absorption coefficients of each constituent element.

The mass absorption coefficient was calculated for kaolin coating clay of the composition indicated in Table II, and for this kaolin u/ρ = 32.19. In order to evaluate the effect of practical extremes of kaolinite composition, the mass absorption coefficients were calculated for a kaolinite of ideal composition, and for kaolin coating clay to which 2.0% Fe_2O_3 had been added. Their respective u/ρ's are 29.64 and 36.20. Using these mass absorption coefficients and assuming a density of 2.61 g./cc. for kaolinite, plots of I/I_0

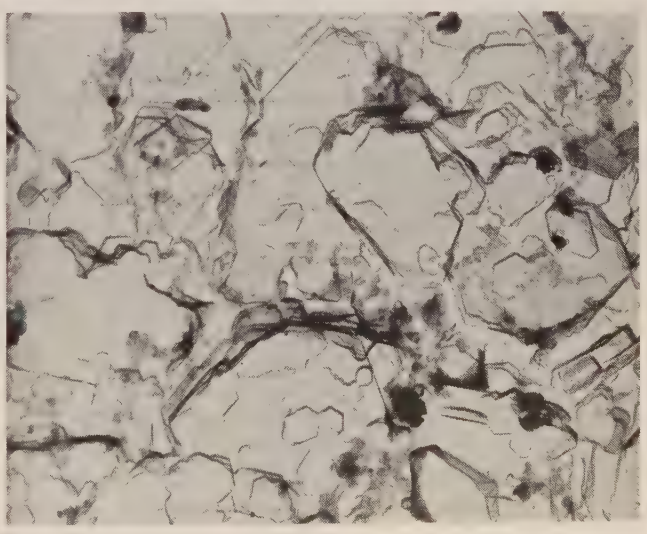

Fig. 1. Electronmicrograph of clay-coated sheet. Magnification 34,000×

HAYDN H. MURRAY, Director of Research and Manufacturing, Georgia Kaolin Co., Elizabeth, N. J., and WILLIAM D. JOHNS, Associate Professor of Geology, Washington Univ., St. Louis, Mo.

Table I. Mass Absorption Coefficients (1.54 A. X-Radiation)
From Compton and Allison (*3*)

Si	60.0
Al	49.0
O	11.16
H	0.48
Fe	328
Ti	213

versus film thickness were made, as illustrated in Fig. 2. For actual thickness measurements the kaolin coating clay composition was assumed and the corresponding curve was used. Any deviation from this composition in practice would result in coating thickness errors substantially less than 1 μ, well within the established accuracy of the method as applied here.

Experimental Determination of I/I_0

The experimental determination of I/I_0 is easily accomplished and requires only the simple conversion of a standard x-ray diffractometer to a spectrometer in order to provide a monochromatic source of radiation. The experimental setup is schematically shown in Fig. 3. A Cu-target tube was used which provided the entire characteristic CuK spectrum as well as the characteristic W_L series as a result of contamination. In addition, at shorter wavelengths the general radiation continuum is emitted. A LiF analyzing crystal ($2d$ = 4.028 A) was utilized to diffract selectively the 2nd order CuK_α (λ = 1.54 A) spectral line. Thus the Geiger counter detector was set at $2\theta = 99.75°$ to admit this radiation only.

Ideally I_0 is measured with the sample removed, and I with the sample in place. We are attempting here to measure the thickness of the coating clay, which cannot be removed from the paper for measurement. Therefore a paper blank which was cut from the same handsheet on which the coating was drawn-down was inserted in the sample position; the x-ray intensity I_0 was counted after passing through the paper. The sample, consisting of paper coated with clay, was inserted in place of the blank and I measured, the reduction in intensity being due to coating clay alone.

In the experiments which follow, a General Electric XRD-5 spectrometer was used, operating at 10 kv. and 5 ma. Geiger tube high voltage was set at 5.4 on the arbitrary scale.

Materials Used

Three rawstocks, a 29-lb. groundwood, a 40-lb. groundwood, and a 45-lb. bleached kraft were used in the study. Starch (16%), casein (15%), and latex (15%) adhesives were used to determine possible variations that might occur because of differences in type of

Table II. Percentage Chemical Composition of a Kaolin Coating Clay

SiO_2	45.3
Al_2O_3	38.38
Fe_2O_3	0.30
TiO_2	1.44
CaO	0.05
MgO	0.25
Na_2O	0.27
K_2O	0.04
H_2O	13.97

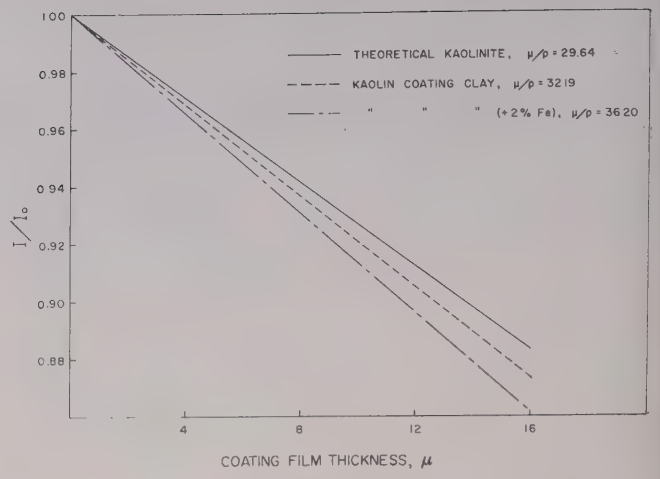

Fig. 2. Plot of I/I_0 vs. film thickness showing relationship to the mass absorption coefficient u/ρ

adhesive in the coating color. Three different kaolin coating clays, KCS, Premier, and REX-A, which differ primarily in particle size distribution, were employed in the coating color.

The sheets were coated using a Mayer rod and weights were determined as follows:

A template, 5.25 by 11.50 in., was used to cut pieces from the rawstock. These pieces were conditioned and accurately weighed, and then coated using a Mayer rod. Another template, 5 by 10 in., was used to trim coated sheets from the above. These coated sheets were again conditioned and weighed. The coat weights were calculated and converted to pounds on a bookmaker's ream basis (25 × 38—500).

Small specimens of paper were cut from near the center of each sheet and mounted for analysis in the filter holder used for diffraction work. The x-ray absorption of each sample was measured in duplicate, three times, several days apart. Calculated clay film thicknesses were reproducible to ±0.2 μ. This value can be considered the precision of the method. Calculated film thicknesses were plotted as a function of coating weight and the resulting plots are given in the figures which follow. Each point shown in Figs. 4, 5, and 6 represents the mean of six separate determinations.

DISCUSSION OF RESULTS

Figure 4 shows that the type of adhesive makes essentially no difference in the absorption and thus in the thickness determination. In Fig. 5, the kaolin coating

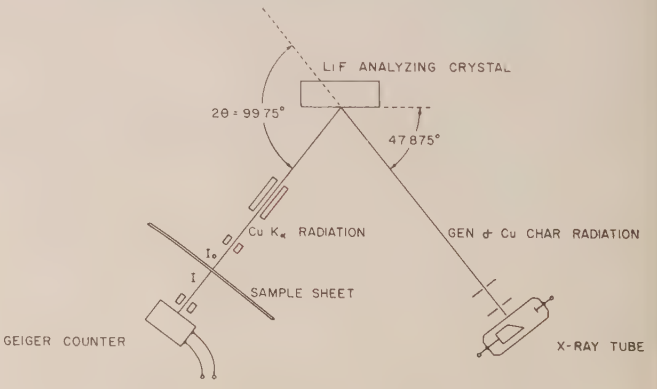

Fig. 3. Diagram of spectrometer

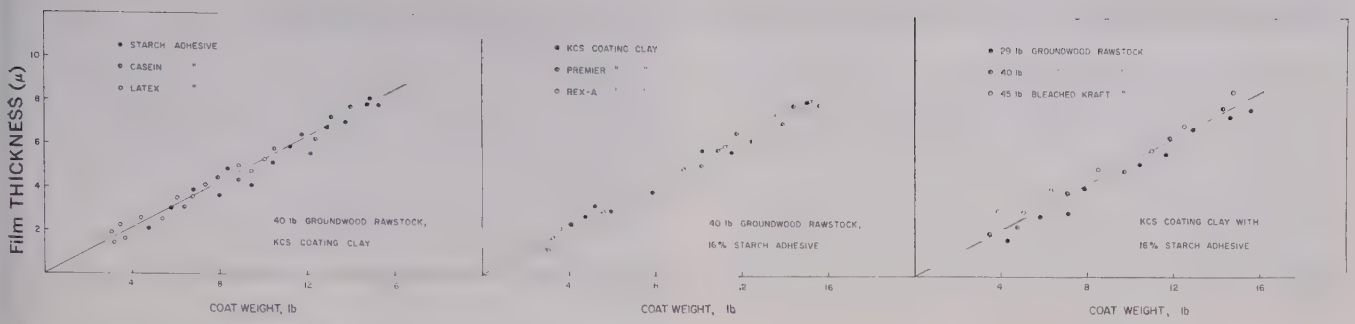

Fig. 4. Plot of coat weight vs. film thickness, varying the adhesive

Fig. 5. Plot of coat weight vs. film thickness, varying the kaolin coating clay

Fig. 6. Plot of coat weight vs. film thickness, varying the rawstock

clay is varied, holding the rawstock and the adhesive constant. As shown in Fig. 5, thickness versus coat weight, the particle size of the kaolin coating clay has no significant effect. As shown in Fig. 6 the rawstock was varied, and within the limits used in this study had no significant effect on the coating thickness determination.

The accuracy of this absorption method is greater than the precision in obtaining uniform coating weights on experimental test papers. The absorption method is capable of determining coating weight differences of the order of 0.2 lb. per bookmaker's ream (25 × 38—500) and a relative thickness of 0.2 μ. However, the scattering of points shows a deviation of about 0.5 μ from the mean. This deviation is attributed to the nonuniformity of the coating clay on a single sheet.

Cobb (*4*) has pointed out that ordinary clay coatings contain approximately 50% pigment by volume and 50% air. Air in the coating absorbs a relatively minute amount of the x-rays in comparison to the kaolin and therefore the micron values for thickness are essentially for solid kaolin. This micron value for thickness as determined by x-ray absorption is therefore more accurately correlated with the coat weight as determined by careful laboratory techniques.

The method employed is simple and it would seem that an x-ray tube with proper shielding devices and collimators could be made so that a small compact unit could be designed for on-the-machine control of coating thickness and weight. This unit could be set to traverse the width of the roll, and accurate control of coating thickness and weight maintained.

The thickness of coating, using other inorganic materials, such as TiO_2, $CaCO_3$, etc., can be determined as easily as kaolin by substituting the proper mass absorption coefficients in the calculation

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A Procedure for Sampling and Analysis for Hydrogen Sulfide in Kraft Mill Stack Gases

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An apparatus and procedure are described for sampling and analysis for hydrogen sulfide in gases from a kraft mill recovery stack. The apparatus permits rapid sampling of the gas stream and the hydrogen sulfide in the sample is absorbed in zinc acetate solution. The resulting mixture is analyzed colorimetrically for sulfide using the Lauth's violet method.

During a recent series of studies carried out at the British Columbia Research Council, it was necessary to devise a method for the analysis of hydrogen sulfide in a large number of gas samples from recovery stacks. The methods described are not substantially novel but represent a combination of techniques and procedures which proved very satisfactory.

The gas samples were collected by a liquid displacement method. The samples were bubbled through zinc acetate solution and the sulfide collected as a precipitate of zinc sulfide. The collection of hydrogen sulfide in zinc acetate solution has been studied by a number of authors (*1, 3*) and worked very satisfactorily in our application.

A colorimetric procedure (*2*) which has been used for the determination of sulfide in black liquor (*4*) was adapted for the analysis of sulfide in the precipitate. This procedure is based on the formation of the color Lauth's violet and is considered preferable to the methylene blue method (*2*).

The procedure of sampling and analysis as described was useful for measuring hydrogen sulfide concentrations ranging from 20 to 800 γ per liter in the stack gas.

REAGENTS

1. Zinc acetate solution containing 20 g. of zinc

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acetate plus four drops of glacial acetic acid per liter of solution.

2. *p*-Phenylenediamine solution containing 2.5 g. of the purified amine (recrystallized from alcohol) and 10 ml. of concd. HCl in 250 ml. of solution.

3. Base electrolyte solution containing 1.6 g. of anhydrous ferric chloride and 40 ml. of concd. HCl in a liter of solution.

4. Displacement liquid for sampling apparatus consisting of a 15% solution of sodium sulfate acidified with 5 ml. of concd. H_2SO_4 per liter. A small amount of potassium permanganate may be added to color the solution.

PROCEDURES

Collection of the Sample

The sampling apparatus is shown in Fig. 1. Flask 1 was calibrated to deliver 1 liter between two marks on the narrow portions of the flask. The sampling probe 5 extended into the duct from which the sample was drawn and was connected to the trap 4 which contained 50 ml. of zinc acetate solution.

To collect a sample, the clamp 3 was removed and the gas sample from the duct passed into the trap 4, where it bubbled through a 0.5-mm. orifice into the zinc acetate solution. The flow rate of the displacement liquid was controlled at about 0.25 liters per minute by the use of a capillary tube restriction 2 in the tubing leading to the reservoir 6. Throughout the sampling period, the trap was immersed in an ice bath so that the zinc acetate level in the trap was below the ice-water level outside the trap.

When one liter of gas had been collected in flask 1, clamp 3 was replaced and the outer envelope and the inner bubbler tube were removed from the trap 4. The bubbler tube was left in the trap envelope and the envelope was sealed with a ground-glass stopper. The trap and contents were then immediately placed in an ice bath.

Development of the Colored Solution

To the material in the trap envelope, 4 ml. of *p*-phenylenediamine solution were added from a blow pipet. The solution was then mixed well by slowly inverting the stoppered trap envelope several times. Fifty milliliters of base electrolyte solution were quickly added and the trap envelope immediately stoppered. The contents of the trap envelope were then thoroughly mixed by inverting a number of times, taking care not to break the bubbler tube.

The trap envelope was next immersed to within one inch of the top in a water bath maintained at room temperature. The solution was allowed to warm and the color to develop for a period of 15 min. The solution in the trap envelope was then diluted by pouring it into a 2-liter measuring cylinder containing 1500 ml. of distilled water. The envelope was rinsed with several portions of distilled water which were added to the cylinder. The volume was made up to two liters and the solution was well mixed. The optical density of the colored solution was measured against a blank at a wavelength of 540 μ.

Calibration of the Analysis

A calibration curve showing micrograms of hydrogen

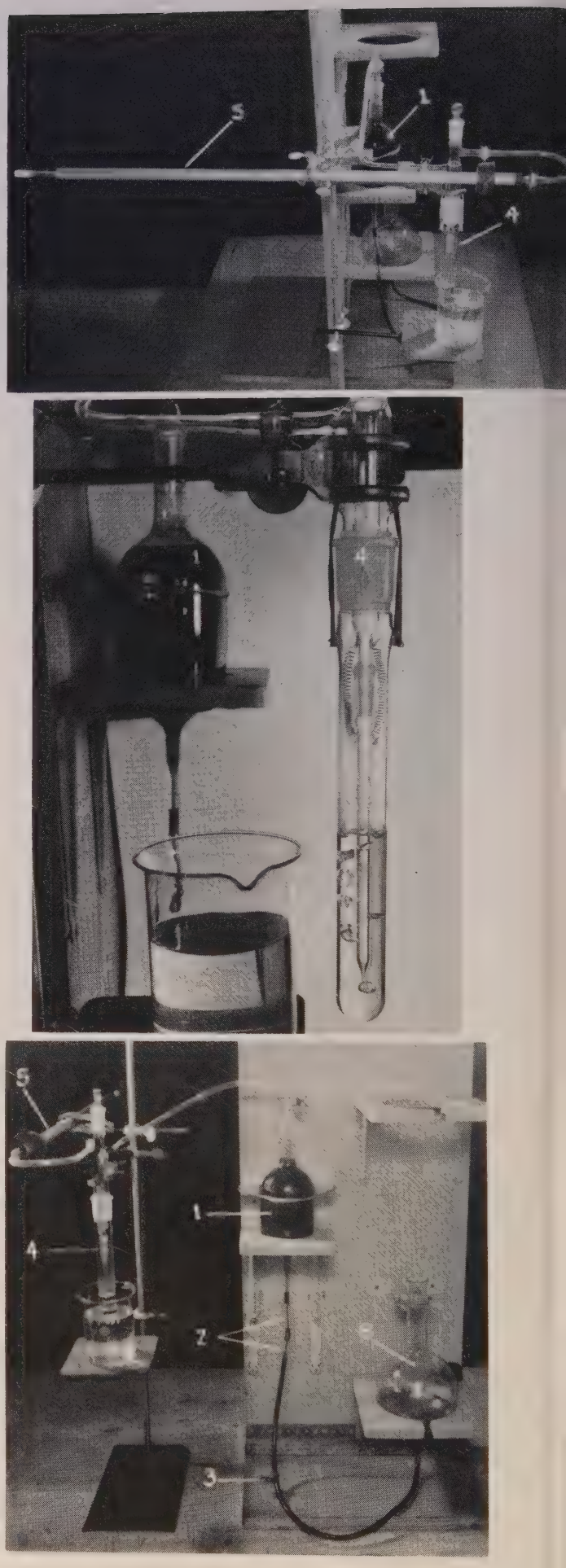

Fig. 1. Sampling apparatus

sulfide as a function of optical density was prepared in the laboratory.

Solutions containing known amounts of sulfide were prepared by slowly injecting measured amounts of hydrogen sulfide into zinc acetate solution. Injection was made using a hypodermic syringe and the zinc acetate was contained in a serum bottle with rubber cap. The resultant mixture was analysed by the colorimetric procedure as described.

Calibration of the analytical procedure is simplified by the fact that the solution obeys Beer's Law over a wide range of optical density.

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The Action of Chlorine on Glucose and Alkyl Glucosides

I. The Quantitative Reduction of D-Gluconic-δ-Lactone to Glucose with $NaBH_4$

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The reduction of D-gluconic-δ-lactone to D-glucose by 2.5 equivalents of $NaBH_4$ at 0°C. in weakly acid solution proceeds quantitatively. With stoichiometric amount of reactants employed at 0°, in the absence of added acid, 90% conversion to D-glucose is realized. Neither procedure provides high conversion to aldose when applied to the following lactones: D-arabonic-γ-lactone, D-galactonic-γ-lactone, D-gluconic-γ-lactone, D-gluco-D-gulo-heptonic-γ-lactone, D-mannonic-γ-lactone.

For some time the kinetics and stoichiometry of reaction of aqueous chlorine with glucose and several alkyl glucosides have been under investigation in this laboratory under the sponsorship of the Fundamental Research Committee of TAPPI. This work, which is directed toward elucidation of catalytic effects and reaction mechanisms, is greatly complicated by the formation of products of attack of oxidant at different positions particularly in glucosides and by the pH dependence of the point of attack (*1–7*). Glucose and alkyl glucosides with deuterium bound to the anomeric carbon atom can serve a dual role in such a study. First, where independent evidence establishes that reaction takes place solely or largely at the anomeric position, the magnitude of the kinetic isotope effect provides an important criterion of mechanism. Second, the presence of a kinetic isotope effect can establish the anomeric carbon as a significant site of attack.

In subsequent publications in this journal the results of studies with both unlabeled and labeled substrates will be described. The present relatively fragmentary communication is presented independently and in advance of its proper chronological place in this series because of its potential interest to workers in the carbohydrate field.

The reduction of D-gluconic lactones provides an attractive route to the preparation on a multigram scale of D-glucose-1-H[2]. The literature reports many examples of the reduction of gluconic lactones to glucose, none of them quite satisfactory in terms of this objective. Thus, catalytic hydrogenation of D-gluconic-γ-lactone (*8*) gave a 24% yield of D-glucose while the hydrogenation of the δ-lactone (*8, 9*) gave an 80% yield. Hydrogenation is wasteful of reductant, however. The sodium amalgam reduction of D-gluconic-γ-lactone (*10, 11*) has been developed to give a 90% yield of glucose (*12, 13*) but this procedure is also wasteful of hydrogen donor. Sodium borohydride has been widely applied in the synthesis of sugars (*14–25*) and has been reported (*20*) to provide a 40% yield of crystalline D-glucose from D-gluconic-δ-lactone. Lithium borohydride has been found (*26*) to be inferior to sodium borohydride in this reaction.

The present work was devoted to establishing conditions for maximum utilization of the reductant in the reaction of sodium borohydride with D-gluconic-δ-lactone. D-gluconic-δ-lactone equilibrates in aqueous solution with the γ-lactone, gluconic acid, and gluconate ion (*27–29*). The position of equilibrium depends on temperature and, with respect to the ratio of the sum of the two lactones and the acid to the gluconate ion, on concentration and pH. Sodium borohydride is a general reagent for the reduction of lactones but does not reduce carboxylic acids or their anions (*30*). This reagent does reduce aldehydes, aldoses (*17, 18*) and sugar lactones (*15*), presumably via aldoses, providing high yields of glycitols in alkaline solution. Thus, conditions which minimize equilibration of δ-lactone with carboxylic acid or carboxylate ion and which avoid the possibility of further reduction of glucose are indicated. The present results also demonstrate that conversion to γ-lactone must be avoided for optimum results. These objectives can be achieved by rapidly reducing at 0°C. a solution of δ-lactone made up in ice water *immediately* before use. The addition of sodium borohydride increases the pH of the solution driving the hydrolytic equilibria toward the unreactive carboxylate ion as well as catalyzing equilibration. This effect can be compensated by employing a weakly acidified reaction medium, but then decomposition of borohydride to yield molecular

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hydrogen competes with the reduction reaction and an excess of reductant must be used.

In the present work two procedures were developed. Method 1 involves the addition of 2.5 equivalents of sodium borohydride ($NaBH_4$) per equivalent of D-gluconic-δ-lactone to a solution of the lactone acidified with 1 mole of acetic acid per mole of borohydride and results in quantitative conversion of the lactone to the aldose as estimated by titration with Benedict's reagent (*31*).* This method is wasteful of reductant. Method 2 involves the use of essentially equivalent amounts of reactants (4 moles of lactone per mole of sodium borohydride) in the absence of acid and results in 90% conversion to D-glucose according to Benedict's titration. Almost the entire product can be isolated in crystalline boron-free form by subsequent treatment with ion exchange resins and methanol. Method 2 has been applied with equal success to the reduction of D-gluconic-δ-lactone with sodium borodeuteride and can be recommended for the preparation of substantial amounts (e.g., several hundred grams) of glucose selectively and quantitatively labeled at C-1.

Neither procedure gives good results with several other sugar lactones. The data of Table I document this conclusion and suggest a distinction between the efficiency of reduction of δ- and γ-lactones. Unfortunately, only one δ-lactone was available to us and this suggestion has not been subjected to further study. These results contrast with the very high yields of glycitols which Frush and Isbell obtained (*15*) in the reduction of all these lactones with sodium borohydride. These workers employed a large excess of this reagent, at least five times the molar ratio of reductant to carbohydrate employed in method 1. It is possible that under the conditions of the work further reduction of the product aldoses competes with reduction of the several γ-lactones and/or that the reactions of the γ-lactones are not complete. These possibilities are consistent with the fact (*32*) that cyclohexanone is reduced by sodium borohydride much more rapidly than is cyclopentanone but more discriminating evidence is lacking.

EXPERIMENTAL

Method 1 (Excess $NaBH_4$ in the presence of acid): An ice cold solution of 0.200 g. (0.0053 mole) of $NaBH_4$† in 10 ml. of water was added dropwise with stirring over a 5-min. period to a solution prepared *immediately* beforehand by dissolving 1.500 g. (0.00842 mole) of D-gluconic-δ-lactone in 40 ml. of ice cold water in which 0.30 ml. (0.0053 mole) of acetic acid had been dissolved. The reaction mixture was stirred in an ice bath for 30 min. after which 0.20 ml. of glacial acetic acid was added and stirring was continued for an additional 15 min. in the cold. Titration with Benedict's reagent (*31*) indicated a 100% yield of glucose.

Method 2 (Stoichiometric amounts of reagents in the absence of acid): Several small scale experiments demonstrated that rapid mixing of ice cold solutions of the reagents results in 85 to 90% conversion to glucose. The reaction was accordingly scaled up 67 fold and the product isolated as follows. Precooled D-gluconic-δ-lactone (99.8 g., 0.56 mole) was dissolved in 3 min. by adding 1000 ml. of water which had previously been cooled to 0°C. and stirring in an ice bath. An ice cold solution of 5.10 g. (0.135 mole) of $NaBH_4$ in 100 ml. of water was *immediately* added over a period of 3 min. After 20 min. of stirring at 0°C. the pH of the solution was 8. No gas was evolved upon addition of 10 ml. of 50% aqueous acetic acid. Titration of aliquots with Benedict's reagent (*31*) indicated a 90% conversion to glucose (based on $NaBH_4$).

Table I. Reduction of Lactones[a] with Sodium Borohydride[b]

Lactone	Conversion to aldose, % Method 1	Conversion to aldose, % Method 2	Benedict's reagent standardized with aldose from
D-Gluconic-δ-lactone[c]	100	90	*f*
B-Arabonic-γ-lactone[d]	Less than 12	30	*d*
D-Galactonic-γ-lactone[d]	Less than 13.5	40	*d*
D-Gluconic-γ-lactone[d]	40	38	*f*
D-Gluco-D-gulo-heptonic-γ-lactone[d]	54	Less than 10	*e*
D-Mannonic-γ-lactone[e]	13	36	*d*

[a] The yields of aldoses were determined by Benedict's titration. The reagent solution was standardized each time with the corresponding aldose.
[b] Metal Hydrides, Inc., Beverly, Mass.
[c] Fisher Scientific Co., Fair Lawn, N. J.
[d] Pfanstiehl Laboratories, Inc., Waukegan, Ill.
[e] We are grateful to Dr. Harriet L. Frush of the National Bureau of Standards for a gift of these samples.
[f] Merck and Co., Inc., Rahway, N. J.

The reaction mixture was next passed through a 62.5 by 3.3 cm. column of Amberlite IR-120 resin.‡ The resin was washed with four 500-ml. portions of water. The combined eluate and washings (which gave a negative flame test for sodium) were then passed through a 75 × 3 cm. column of Duolite A-4 resin.§ The column was washed with seven 500 ml. portions of water and the combined eluate and washings were evaporated at 50°C. under water aspirator vacuum in a Rinco Rotating Evaporator.‖ The resulting syrup gave a positive turmeric paper test (*34*) for boron. A negative test for boron was obtained after evaporating a solution of the syrup in 500 ml. of methanol (*35*) (Baker's "Analyzed Reagent") to dryness under water aspirator vacuum in the Rinco evaporator. The product was evaporated to dryness with two additional 200-ml. aliquots of methanol. Upon treatment of the residue with 150 ml. of methanol, crystals appeared. The suspension was stored in the refrigerator over night, after which the product was filtered and dried to provide 78.1 g. of white crystals melting at 147–151°C.; mixed melting point with Merck's "Reagent" anhydrous glucose recrystallized from methanol 147–151°C.; $[\alpha]_D$ = + 58.5° 5 min. after dissolution, +52.7° at equilibrium (c = 0.04 g./ml. in water). The mother liquor yielded a second crop of crystals weighing 6.47 g. and melting at 146–150°. The combined yield of crystalline product based on the $NaBH_4$ employed was thus 86%.

* A smaller excess of $NaBH_4$ does not give a quantitative yield under these conditions.

† Metal Hydrides, 100% purity by gasometric analysis (*33*).

‡ Rohm and Haas Co., Philadelphia, Pa.

§ Chemical Process Co., Redwood, Calif.

‖ Rinco Instrument Co., Inc., Greenville, Ill.

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Comparative pH Measurements on Papers by Water Extraction and Glass Electrode Spot Tests

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The pH of a large number of experimental and commercial papers was determined by the TAPPI Standard T 435 cold-extraction method and a method in which glass-calomel electrodes were pressed against the surface of the papers, moistened with either distilled water or 0.1 *N* KCl solution. The use of potassium chloride solution instead of water gave better reproducibility, less time variation, and values, on an average, about 0.4 pH units lower. Correlation between the spot tests and extraction pH's was rather poor, especially for papers of high extraction pH. Few generalizations could be made concerning the effects of the types of pulp or added chemicals upon the pH values. It appears that other variables in the papermaking, blending, and pulping cause considerable variation in measured pH values of the paper. Because of the complicated nature of the chemical and physical processes involved, none of the methods can be judged to be superior to the others *per se*, but the spot test merits consideration in cases where a quick, nondestructive method is needed.

THE MEASUREMENT of the pH of water extracts of paper and other cellulosic materials has been widely employed as a test method in research and as an industrial control. A typical extraction method is TAPPI Standard T 435. Here, 1 g. of paper is macerated and extracted with 70 ml. of water, and the pH of the water—paper mixture is measured with glass–calomel electrodes. The principal shortcomings of these extraction methods are that they take several hours in execution, are destructive, and give no direct information concerning the acidity of the dry paper.

In this report, a method involving the use of glass–calomel electrodes pressed against a moistened paper surface (*1*) is compared with the conventional water-extraction method.

The results demonstrate that the close correlation between the two methods, as found by Hudson and Milner (*1*) for several papers, does not occur when a wide variety of papers is tested. Possible causes of this lack of correlation are discussed in this report.

EXPERIMENTAL

Experimental and commercial papers covering a broad range of properties were selected. These papers are described in Table I. The cold-water-extraction pH of the paper samples was determined by the TAPPI Standard T 435.

For the spot test, the paper was placed on a soft, inert backing material. In most of this work a thick glass-fiber paper was used. This backing material was found to be neutral (pH = 6.7) and to have no measurable buffering capacity. An area of paper of approximately 2 sq. cm. was moistened with 2 to 3 drops ($\approx$ 0.1 g.) of either distilled water or 0.1 *N* KCl solution, and the electrode probe assembly was lowered onto the moistened spot. The pH was read from a pH

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Table I. Papermaking Details and Extract and Spot Test pH Values of Various Papers

Papers listed in order of decreasing cold extraction pH

Sample no.[a]	Fibers used	Alum, %	Clay, %	Rosin, %	Starch, %	TiO_2, %	pH of tray water	$CaCO_3$, %	Other beater furnish and distinguishing characteristics	pH extract[b]	pH H_2O[c]	pH KCl[d]
G2	.....	..	..	..	..	..	..	Present	Commercial permanent-type book paper	8.9	7.1	6.3
G1	Sulfate 33%, sulfite 33%, soda 33%	..	10.0	..	7.0[e]	..	..	10.0	60-lb (89 g.s.m) permanent-type book paper (machine- sized with Aquapel)	8.8	6.9	6.0
D1	Broke 25%, sulfate 75%	2.8	..	..	..	..	..	23.0	40-lb (77 g.s.m.) white rotogravure	8.4	7.2	6.3
1174	Sulfate 50%, soda 50%	..	..	..	..	..	8.2[f]	15.0	Precipitated $CaCO_3$, book paper	7.8	6.2	5.2
1158	Sulfate 50%, soda 50%	..	..	..	..	..	7.7[f]	30.0	Natural $CaCO_3$, book paper	7.3	6.3	5.1
1176	Rags, no. 1 new white 100%	0.5	15.0	..	..	..	6.6[f]	..	.....	6.5	5.3	4.7
1133	Sulfite 50%, soda 50%	..	..	..	..	..	7.3[f]	..	.....	6.2	5.5	4.8
C16	Cold-caustic birch 40%, spruce chip groundwood 40%, hot neutral sulfite impregnated spruce 20%	..	..	..	..	..	..	..	32-lb (51 g.s.m.) newsprint	6.1	6.6	6.0
C18	Cold-caustic birch 50%, spruce chip groundwood 50%	..	..	..	..	..	..	..	32-lb (51 g.s.m.) newsprint	6.1	6.3	5.9
1370	No. 1 white shirt cuttings 50%, no. 1 old white rags 50%	..	20.0	..	..	..	..	..	.....	6.0	5.7	4.6
E3	Bleached kraft (pine 50%, hardwoods 50%)	..	12.0	2.0	2.0	..	5.1	..	41-lb (77 g.s.m.) tablet	5.9	5.6	4.6
E6	Bleached kraft (pine 50%, hardwoods 50%)	..	20.0	1.5	2.0[e]	..	5.1	..	50-lb (74 g.s.m.) offset	5.9	5.7	4.7
E1	Bleached kraft (pine 50%, hardwoods 50%)	..	20.0	2.0	2.0[e]	..	4.6	..	50-lb (74 g.s.m.) offset	5.9	5.6	4.6
F1	Neutral sulfite semichemical (bleached deciduous) 95%, bleached coniferous sulfite 5%	..	..	[e]	[e]	0.7	..	..	White bond	5.8	5.4	4.4
C8	Cold-caustic birch 28%, spruce chip groundwood 28%, hot neutral sulfite impregnated spruce 44%	..	..	..	..	..	..	..	Corrugating	5.7	5.7	6.0
E4	Bleached kraft (pine 50%, hardwoods 50%)	..	30.0	1.5	[e]	..	4.9	..	50-lb(74 g.s.m.) offset	5.7	5.7	4.5
A5	Bleached bamboo 100%	..	..	..	..	..	..	..	.....	5.6	5.6	5.5
C10	Birch chemigroundwood 50%, NSSC birch 50%	..	..	..	..	..	..	..	Corrugating	5.6	6.8	5.8
C11	Unbleached kraft 15%, birch chemigroundwood 35%, NSSC birch 50%	..	..	..	..	..	..	..	Corrugating	5.6	5.8	5.8
C15	Unbleached kraft 50%, bagasse (depithed) 50%	..	..	..	..	..	..	..	Linerboard	5.6	6.1	5.9
1134	Sulfite 50%, soda 50%	0.5	15.0	..	..	..	7.0[f]	..	.....	5.5	5.4	4.5
C14	Unbleached kraft 100%	..	..	..	..	..	..	..	Linerboard	5.5	6.2	5.7
C17	Jack pine chip groundwood 90%, bleached sulfite 10%	2.0	..	..	..	..	..	..	Newsprint	5.4	5.8	4.8
D6	Broke 11%, sulfate 15%, sulfite 74%	5.8	..	1.3	4.5	2.8	..	..	Calcium sulfate 5.5% white bond, tub-sized 6% starch	5.4	5.4	4.5
D8	Broke 14%, sulfate 57%, sulfite 29%	2.1	8.0	1.2	2.0	1.0	..	..	Calcium sulfate 24.0% white duplicator tub-sized 6% starch	5.3	5.2	4.6
E2	Bleached kraft (pine 50%, hardwoods 50%)	..	12.0	2.0	2.0	..	4.3	..	41-lb (77 g.s.m.) tablet	5.3	5.4	4.5
E5	Bleached kraft (pine 50%, hardwoods 50%)	..	12.0	2.0	2.0	..	4.7	..	41-lb (77g.s.m.) tablet	5.3	5.3	4.4
1125	Soda 50%, sulfite 50%	..	..	..	..	..	..	..	.....	5.3	5.8	4.5
B4	Sweet gum bleached chemigroundwood 60%, southern pine bleached sulfite 40%	..	..	0.5	..	..	..	..	Book, coating base stock	5.3	5.8	5.3
C6	Bleached sulfite 20%, groundwood 50%, straw pulp 30%	2.0	32.0	1.0	..	..	..	..	Book paper	5.3	5.8	5.3
C19	Semibleached kraft 10%, spruce groundwood 60%, birch chemigroundwood 30%	2.0	7.0	1.0	..	..	..	..	Newsprint	5.3	5.2	4.9
1179	No. 1 new white rags 100%	0.9	15.0	2.0	..	..	6.6[f]	..	.....	5.2	5.3	4.5
D7	Broke 14%, sulfate 54%, sulfite 32%	3.0	8.0	1.2	2.0	1.0	..	..	Calcium sulfate 24.0%, white duplicator tub-sized 6% starch	5.2	5.1	4.5
B1	Bagasse bleached soda 50%, spruce–aspen groundwood 30%, spruce bleached sulfate 20%	..	10.0	1.0	..	..	..	..	Book, coating base stock	5.2	5.9	5.5
B5	Aspen bleached cold soda 100%	..	6.0	0.5	..	..	..	..	Book, coating base stock	5.2	5.4	5.3
C5	Groundwood 70%, bleached bagasse 30%	1.0	12.0	0.5	..	..	..	..	.....	5.2	5.8	5.4
C21	Bleached sulfite 51%, bleached straw 49%	3.0	10.0	2.0	..	..	..	..	Straw bond	5.2	5.6	5.2
1139	Sulfite 50%, soda 50%	0.8	15.0	1.0	..	..	6.2[f]	..	Book paper	5.1	5.1	4.3
C4	Bleached sulfite 40%, bleached soda 60%	2.0	32.0	1.0	..	..	..	..	Book	5.1	6.0	5.5
C9	Birch groundwood 100%	..	..	..	..	..	..	..	Corrugating	5.1	5.6	5.6
C13	Waste kraft cuttings 15%, bagasse (depithed) 85%	..	..	..	..	..	..	..	Corrugating	5.1	6.1	6.0
C20	Groundwood (spruce) 80%, semibleached kraft 20%	2.0	..	..	..	..	..	..	Newsprint	5.1	5.5	5.3
1160	Purified wood pulp	..	15.0	..	..	..	7.0[f]	..	.....	5.0	5.1	4.4
D5	Broke 11%, sulfite 74%, sulfate 15%	5.2	..	1.3	4.5	2.8	..	..	Calcium sulfate 5.5%, white bond tub-sized 6% starch	5.0	4.8	4.4
B8	Mixed hardwoods, bleached neutral sulfite semichemical 75%, western softwoods bleached sulfate 15%, commercial bleached sulfite 10%	..	15.0	..	..	..		.	Book, coating base stock	5.0	4.8	4.9
B9	Bamboo bleached sulfate	..	..	1.5	..	2.0	..	..	Lithograph	5.0	5.5	5.1
1602	Eastern sulfite 50%, strong soda 50%	..	..	1.0	..	..	..	..	Offset paper, Uformite No. 467 to beater 3%	4.9	5.0	4.5
B7	Douglas-fir bleached sulfate (ClO_2 in 5th stage) 50%, commercial sweet gum bleached sulfate 50%	..	5.0	1.5	..	..	..	..	Bond paper	4.9	5.1	4.7
B10	Bamboo bleached sulfate	..	18.0	0.8	..	10.0	..	..	Offset	4.9	5.1	4.9
C2	Bleached sulfite 50%, groundwood 50%	2.0	32.0	1.0	..	..	..	..	Groundwood book	4.9	5.2	4.9
B3	Bagasse bleached soda (Hydrapulper)	..	25.0	1.0	..	..	..	..	Book, coating base stock	4.8	5.5	5.4
B6	Aspen bleached cold soda 60%, spruce–aspen bleached groundwood 40%	..	6.0	0.5	..	..	..	..	Book, coating base stock	4.8	5.0	4.7
C1	Bleached sulfite 20%, groundwood 80%	1.0	8.0	0.5	..	..	..	..	Standard newsprint	4.8	5.1	4.7
C3	Bleached sulfite 51%, straw pulp 49%	3.0	12.0	1.5	..	..	..	..	.....	4.8	5.2	5.1
A4	Cold-caustic hardwood mix	..	..	..	..	..	..	..	.....	4.7	6.3	6.0
D2	Sulfite 75%, sulfate 25%	6.2	..	1.4	6.4	0.7	..	..	CMC 1.8%, green tint, direct process, tub-sized PVA	4.7	4.7	4.3

D3	Sulfate	3.6	..	1.4	3.0	1.2	..	White, Direct Process, tub-sized PVA	4.7	5.0	4.5
1182	No. 1 new white rags	4.0	15.0	2.0	..	..	4.0[f]	Book paper	4.5	5.2	4.4
A1	Florida saw grass	..	..	..	..	..	..	..	4.5	6.4	6.2
B2	Commercial bleached soda 50%, straw bleached soda, 30%, spruce bleached sulfite 20%	..	20.0	2.0	..	..	..	Book paper	4.5	5.2	5.1
C7	Bleached sulfite	2.0	..	..	..	..	..	Waxing base	4.5	5.0	5.0
C12	Bagasse (depithed)	..	..	..	..	..	..	Corrugating	4.5	4.4	4.2
1141	Sulfate 50%, soda 50%	2.4	15.0	1.0	..	..	1.2[f]	Book paper	4.4	4.7	4.3
A3	Sugarcane bagasse, alkaline cook	..	..	..	..	..	..	..	4.4	5.3	5.0
1138	Sulfate 50%, soda 50%	2.3	15.0	2.0	..	..	1.2[f]	Book paper	4.3	4.8	4.2
A2	Gum groundwood 80%, bleached kraft 20%	..	..	..	..	..	..	..	4.2	4.5	4.5
1186	No. 1 new white rags	4.0	15.0	1.0	..	..	4.0[f]	Book paper	4.2	4.6	4.3
D4	Broke 18%, sulfate 28%, sulfite 53%	4.1	6.0	1.6	3.6	..	..	Mimeo paper, diatomaceous filler 4.0%	3.0	3.4	3.2

[a] Samples numbered without letters refer to runs on the semicommercial mill at the National Bureau of Standards. Lettered samples refer to commercial and experimental papers received from various sources. [b] TAPPI Standard T 435, cold extraction. [c] Spot test with distilled water as described in text. [d] Spot test with 0.1 *N* KCl as described in text. [e] Surface sized. [f] pH at headbox. [g] Neutral sulfite semichemical.

meter within 5 to 10 sec. after wetting. The electrodes used in these experiments were the Beckman No. 39167 glass electrode and the No. 39168 reference electrode, combined in a conveniently small assembly.

RESULTS

The values for pH obtained from the TAPPI cold-extraction method, pH_E, are plotted against the average values for pH obtained from the spot tests with distilled water, pH_W, for the various papers in Fig. 1. The pH_W values tended to be somewhat erratic and drifted to lower values with time. The latter is illustrated for several samples in Table II.

The use of 0.1 *N* KCl solution in place of distilled water led to much better reproducibility, and the values were, in general, lower. The average difference between replicate values was 0.171 pH units for pH_W and only 0.078 pH units for pH_K, the pH obtained from spot tests with 0.1 *N* KCl solution. pH_K is plotted against pH_E in Fig. 2. In Fig. 3, pH_K is plotted against pH_W.

The pH_K did not decrease by more than 0.2 pH units after the spot tests had been allowed to stand for 10 min. The pH_K was, in many cases, quite close to the limiting pH_W at increasing time. These results appear to indicate that a pseudoequilibrium is much more rapidly approached in the presence of an electrolyte. This lower pH of the potassium chloride solution may result from an ion exchange process. The pH values were relatively independent of the electrolyte used and of its concentration. This is demonstrated for several paper samples in Table III, where the pH values for spot tests using

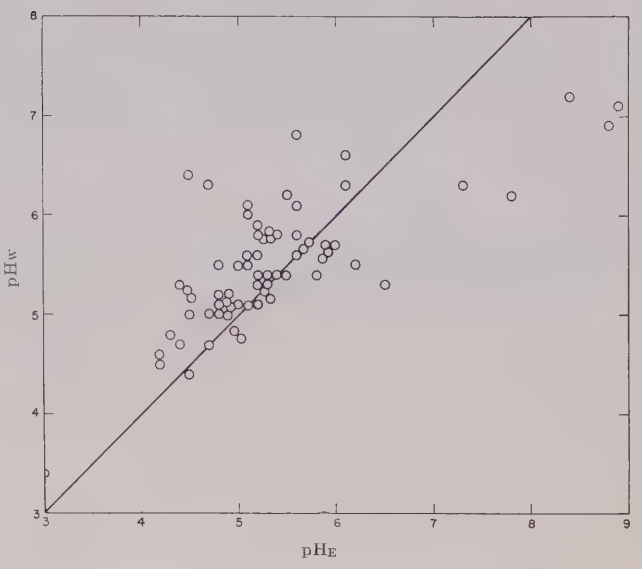

Fig. 1. pH_W (water spot test) plotted against pH_E (TAPPI Standard T 435)

45° diagonal is line of one-to-one correspondence.

0.1, 0.5, and 1.0 *N* KCl and 0.1 *N* $NaNO_3$ solutions are given.

DISCUSSION

The ability of an aqueous potassium chloride solution extract to give a lower pH value than a water extract has been noted by Munds (*2*) and Burton (*3*).

It is difficult to even estimate the relative effects upon pH of the various physical and chemical processes taking place during the extraction of these papers with either water or salt solution. The penetration or wetting of the paper, the solution of soluble constituents in the paper, ion exchange processes, hydrolysis reactions, etc., are all involved and may take place at widely varying rates. Considerable research would be necessary for one to be able to determine how closely true equilibrium is approached in many of these processes.

The comparison of pH_W with pH_E from Fig. 1 indicates that, with the exception of several of the highest pH_E values, pH_W tends to be higher in value than pH_E. The range of pH_W is slightly compressed when compared with pH_E. One-to-one correspondence between pH_W and pH_E would fall on the 45° diagonal passing through the origin.

pH_K may be compared with pH_E in Fig. 2. Here, the correlation appears to be a little poorer than between pH_W and pH_E in Fig. 1, as the papers of high cold-extract pH give even lower values when determined by the potassium chloride spot test than by the water spot test.

Table II. pH Values from the Distilled Water Spot Test at Various Wetting Times for Several Paper Samples

Time, sec.	*Sample no.*				
	D4	*1182*	*1141*	*B8*	*B9*
5	3.5	4.9	5.0	5.1	5.2
10	3.3	4.8	4.9	5.1	5.1
20	3.3	4.7	4.8	5.0	5.1
40	3.2	4.7	4.7	5.0	5.0
60	3.2	4.6	4.6	4.8	5.0
120	3.1	4.5	4.4	4.6	4.9
240	3.1	4.5	4.3	4.3	4.8

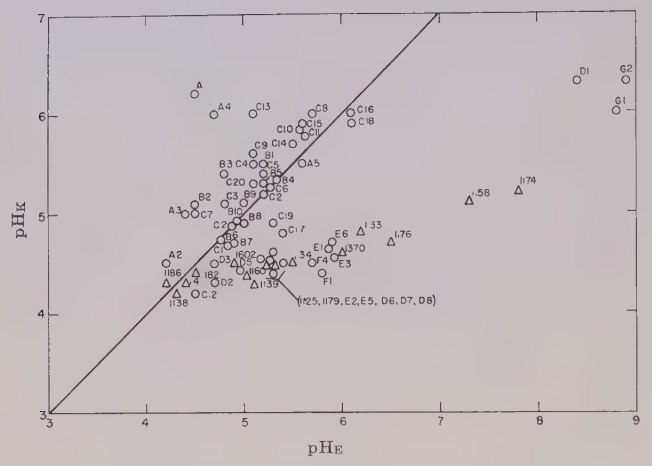

Fig. 2. pH_K (potassium chloride spot test) plotted against pH_E (TAPPI Standard T 435)

Δ National Bureau of Standards mill runs.

From Fig. 2 and Table I a few general observations have been made:

1. pH_K gives quite low values for calcium carbonate papers. The pH_E is around 8 to 9 for calcium cabonate papers, which is about what one would expect for the hydrolysis of calcium carbonate. The much lower values of the spot tests may result from a much greater absorption of carbon dioxide from the air due to a very much greater surface to volume ratio. This would cause a considerable drop in the pH of the weakly buffered, sparingly soluble, carbonate solution.
2. Alkaline cook and kraft papers with no added chemicals were grouped about a pH_K of 6 whereas their pH_E's ranged from 4.5 to 6.1.
3. Alkaline cook papers with added chemicals gave lower pH_K's, but, in general, these values were higher than the respective pH_E's.
4. Sulfite papers mainly gave higher pH_E's than pH_K's.
5. The National Bureau of Standards mill runs (see triangles in Fig. 2) all gave approximately the same pH_K while their pH_E's were much more sensitive to added chemicals.

Little further generalization could be made in the correlation of data in Table I with pH. Therefore, variables in the pulping, blending, and papermaking processes that are not described in this table must be responsible for many of the variations of pH measured by either method. For example, samples D6 and D8 contain widely differing amounts of alum, clay, and calcium sulfate, but both give approximately the same pH_W and pH_E. On the other hand, samples C12 and C13, both depithed bagasse corrugating boards with no added chemicals, differed by 0.7 pH units for cold water extraction and by 1.7 pH units for the spot test.

From pH_K plotted against pH_W in Fig. 3, a good correlation is obtained. pH_K's average about 0.4 pH units lower than pH_W's. In many cases, where the rate of change of pH_W with respect to time was obtained, the pH_K's were close to the respective limiting values of the pH_W's.

Table III. pH Values from Spot Tests with Several Concentrations of Electrolytes for Several Paper Samples

Sample no.	*0.1 N KCl*	*0.5 N KCl*	*1.0 N KCl*	*0.1 N $NaNO_3$*
C18	5.9	5.8	5.8	6.0
B4	5.3	5.1	5.1	5.3
B8	4.9	4.7	4.8	4.9
B9	5.1	5.2	5.0	5.3

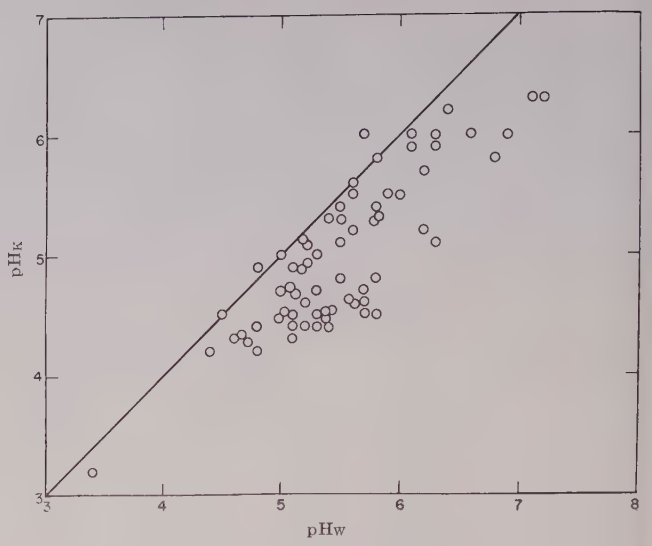

Fig. 3. pH_K (potassium chloride spot test) plotted against pH_W (water spot test)

CONCLUSIONS

The substitution of 0.1 *N* KCl solution for distilled water in the spot tests gives more reproducible results, and appears to permit extraction from the paper samples to occur more quickly and completely.

In both the water-extraction method and the potassium chloride spot-test method, the precise nature of the extraction processes involved is unknown. Therefore, it is impossible to say which method is better. Each method has certain practical advantages and disadvantages. A comparison of the correlation of each method with the particular property of interest to the experimenter, e.g., aging characteristics of the papers, would indicate which method might be a better criterion of that property.

The traditional water-extraction method appears to spread the pH values out over a wider range and, therefore, may be considered to be a somewhat more sensitive differentiator of paper samples. In this method the pH is determined at greater dilution, so changes in pH resulting from high concentrations and ionic strength should be less The strongest argument for the continuance of the extraction method is the large mass of experimental and control process data with which it has been correlated for a great many years.

The chief disadvantages of the water-extraction method are that it is destructive (important in archival work, for example) and that it takes several hours to execute.

Conversely, the principal advantages of the potassium chloride spot test are that it is nondestructive and quick. Also, it is more of a measure of the readily realizable acidity or alkalinity of a sample and does not allow as much time for side reactions to take place.

Among the disadvantages of the potassium chloride spot test method are: pseudoequilibrium may not be so nearly approached, deviations in pH may result from higher concentrations and ionic strength, the rate of wettability becomes important, and the amount of sample extracted per amount of solution used will

vary from sample to sample. Some of these effects may be interrelated, of course.

From this discussion, one may conclude that the potassium chloride spot method may merit application in cases where rapidity of execution and preservation of the test specimen are of importance.

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The Chemical Composition and Some Physical Properties of Hawaiian Forest Woods

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The composition of recommended species for forest planting in Hawaii was determined using generally recommended procedures. The analytical results obtained were compared with those obtained for wood samples of Douglas-fir which originated from the Pacific Northwest. The extractives and hemicellulose content of Norfolk Island pine, loblolly- and slash pines were generally low in comparison to the values obtained for other tropical trees. Loblolly- and slash pine contained 49% alpha-cellulose compared to 50% for Douglas-fir. Norfolk Island pine contained 45% alpha-cellulose while other species investigated contained only 34 to 42%. The D.P. of the alpha-cellulose from loblolly- and slash pine was found to be 550 and 530, respectively; whereas the D.P. of the cellulose from Norfolk Island pine was 430. The alpha-cellulose prepared from wood of Douglas-fir had a D.P. of 520. Norfolk Island pine had a higher lignin content (31%) than did loblolly- and slash pine and Douglas-fir (25–27%). The density of Norfolk Island pine and loblolly and slash pine was 0.51 g./cc. or less, whereas one of the Eucalpytus species was heavier than water with a density of 1.05 g./cc.

THE CONSUMPTION of lumber, paper, and paper products in Hawaii is almost entirely satisfied by shipment from the United States mainland or by foreign sources. In general, a forestation program had to be initiated to establish stands of timber which showed rapid growth and desirable commercial qualities. Only recently was part of the state-owned timber considered ready for harvesting. Apparently about 100 million board feet of lumber is available and most of this is comprised of *Eucalyptus robusta* stands on the islands of Maui and Hawaii. Various other tree species have been introduced (*1*) which possess a wood of a lesser density.

In areas of high rainfall, certain introduced species show remarkably rapid growth. The silk oak (*Grevillea robusta*), considered a weed and brush by ranchers, grows very rapidly and is valued as a timber tree by foresters and lumbermen (*2*). Shamel ash (*Froxinus uhdei*), toona or Australian red cedar (*Toona ciliata* var. *australis*), Norfolk Island pine (*Araucaria excelsa*), loblolly pine, and slash pine are some of the 12 recommended (*1*) saw timber trees which show good growth potentials.

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The physical and general commercial properties and general growth aspects of some of the Hawaiian forest trees have been reported (*3, 4, 5, 6*). Information regarding chemical composition and properties is generally lacking. The results of some chemical investigations undertaken by the authors are reported in this communication.

EXPERIMENTAL METHODS

Preparation of Samples. Fine sawdust (20 mesh) was prepared from planed boards of the various species investigated. In general, a representative sample was obtained which would contain material both from the peripheral and interior wood in the approximate ratio that would be normally found. The air-dried sawdust was kept in tightly closed screw-cap jars until used for analysis.

Moisture. The moisture content of the air-dried sawdust samples was determined by drying samples, in triplicate, to constant weight at 95°C.

Extractives (water and alcohol solubles). Extractives were determined by an ether extraction (TAPPI Standard T 5m) (*7*) followed by extraction with 95% ethanol and then with a 1:2 mixture of ethanol:benzene (TAPPI Standard T 6 m) (*7*). The dried residue was further extracted with boiling water (2.5 hr.) and the residue dried to constant weight at 100°C.

Hemicelluloses. The hemicellulose content of the woods was determined by recommended procedures of Wise and co-workers (*8*).

Lignin. The lignin content was determined by TAPPI Standard T 13 m (*7*).

Ash. The ash content was determined by ignition of samples (in triplicate) in an electric muffle furnace.

Alpha-Cellulose. The cellulose of the woods was determined by a modification of TAPPI Standard T 203 m (*7*) by delignifying the pulp samples by a chlorite treatment prior to analysis (*9*).

D.P.$_{no.\,av.}$ of the Alpha-Cellulose. The number average D.P. of the cellulose molecules was determined by a chemical method (*10*) as follows. Suitable quantities (0.6 to 1.0 g.) of alpha-cellulose were soaked in *N* NaOH (20 ml.) containing potassium borohydride (250 mg.). The reduction (*11*) was allowed to proceed for 48 hr. after which time the excess reducing agent was decomposed by acidification with glacial acetic acid (2 ml.). To the mixture was then added an excess of 15% molar periodic acid and the volume of the

Table I. Summative Analysis of Hawaiian Forest Woods

Species	Extractives, %	Hemicellulose, %	Alpha-cellulose, %	Lignin, %	Ash, %	Total
Cedrela odorata (Spanish cedar)	26.7	11.7	34.0	25.3	1.20	98.90
Toona ciliata var. *australis* (Australian red cedar)	21.6	13.8	36.6	24.7	1.62	98.32
Eucalyptus robusta (Beakpod robusta)	16.4	11.5	40.5	29.8	0.39	98.59
E. saligna (Blue gum)	16.7	10.7	39.4	32.5	0.29	99.59
E. citriodora (Lemon gum)	14.3	15.5	36.5	31.0	0.88	98.18
E. pilularis (Black butt)	19.0	10.6	38.5	29.5	0.50	98.10
Flindersia brayleyana (Hawaiian silkwood)	15.3	16.7	35.7	30.2	1.20	99.10
Grevillea robusta (Silk oak)	24.7	12.4	38.6	20.4	1.39	97.49
Samanea saman (Monkey pod)	17.1	18.3	37.5	24.4	2.48	99.78
Fraxinus uhdei (Shamel ash)	14.6	17.9	42.0	22.8	1.52	98.82
Albizzia moluccana (Albizzia)	15.4	18.2	40.2	23.7	2.08	99.58
Araucaria excelsa (Norfolk Is. pine)	10.8	10.3	45.5	31.4	0.73	98.73
Pinus carbaea (Loblolly pine)	11.8	11.3	49.2	25.7	0.68	98.68
Pinus taeda (Slash pine)	11.8	11.5	49.3	26.5	0.40	99.50
Pseudotsuga taxifolia[a] (Douglas-fir)	12.9	10.8	50.2	24.8	0.13	98.83

[a] Specimen from Pacific Northwest of U. S. mainland.

mixture adjusted as desired with water (35 to 40 ml.). The oxidation mixture was left in a refrigerator (5°) for 48 hr. after which time, aliquots of the mixture were periodically withdrawn for formaldehyde determinations.

The formaldehyde produced by the periodate degradation from the glucitol end-residue was determined as follows: to an aliquot (2 ml.) of the periodate oxidation mixture was added saturated lead acetate (3 ml.) and distilled water (10 ml.). The solution, after mixing, was filtered. To aliquots (1 ml.) of the clear filtrate in conical centrifuge tubes (15-ml. capacity) was added chromatropic acid reagent (*12*) and the precipitate of lead sulfate removed by centrifugation. The clear solution was decanted into optically matched borosilicate tubes and the contents heated (light excluded) in a boiling water bath for 30 min. The tubes were cooled in running tap water and the absorbance determined with a spectrophotometer at 570 μ. Formaldehyde calibration curves were constructed by applying the above procedure to erythritol, from which two moles of formaldehyde are generated per mole of erythritol. Redistilled ethylene glycol or glycerol may also be used. On the basis that two molecular proportions of formaldehyde are produced (from the glucitol end-residue) per molecule of cellulose, the average D.P. of the alpha-cellulose may be calculated as follows:

$$\frac{\text{Wt. of sample} \times 30 \times 2}{\text{Wt. of } CH_2O \text{ produced} \times 162} = \text{D.P.}_{\text{no. av.}}$$

$$\text{D.P.}_{\text{no. av.}} \times 162 = \text{M.W.}$$

Density of the Woods. The density of the woods was estimated by determining the displacement volumes of suitable samples.

RESULTS AND DISCUSSION

Table I summarizes the analytical values for extractives, hemicellulose, alpha-cellulose, lignin, and ash. The values are expressed on a moisture-free basis.

The amount of extractives found in Norfolk Island pine, slash- and loblolly pine was generally low compared to that found in woods of such species as *Cedrela odorata*, *Toona ciliata*, *Grevillia robusta*, and the Eucalypts in general. The highest quantities of hemicellulose were found present in Shamel ash, monkey pod, Albizzia, and Hawaiian silkwood. The hemicellulose in the Eucalyptus species was below 12%, except for *Eucalyptus citriodora*. The hemicellulose content of Norfolk Island pine and slash- and loblolly pine was also low and comparable to the amount found in Douglas-fir.

Shamel ash, monkey pod, silk oak, and Albizzia were relatively low in lignin while the eucalyptus species were found, in comparison, to be consistently high in lignin. The lignin content of Hawaiian-grown slash- and loblolly pine is quite comparable to the values found for these species elsewhere (*8*, *13*). In comparison, Norfolk Island pine possessed a somewhat higher lignin content. In general, the lignin content of the tropical woods investigated falls into the range found by Wise, *et al.* (*14*).

A considerable range in the alpha-cellulose content was found in the 15 species examined. The amount of alpha-cellulose in loblolly- and slash pine compared favorably with the cellulose content of Douglas-fir. Shamel ash and Norfolk Island pine contained somewhat lower amounts of alpha-cellulose. All of the other species examined contained less than 41% alpha-cellulose. With respect to the cellulose content of the woods and their potential use for pulping, it would appear that both loblolly- and slash pine would be suitable. Although Norfolk Island pine contains somewhat less alpha-cellulose, its general compositional and growth characteristics are such that it may be included in the same category. Shamel ash, although it was found to contain about 8% less alpha-cellulose than loblolly or slash pine, has a rather white wood and could also be considered a potential pulp source.

The Eucalypts, Spanish cedar, and Australian red cedar are highly pigmented woods, high in extractives and generally low in alpha-cellulose. On this basis, they would be inferior as pulp sources. For timbers and specialized building purposes, their much greater strength is advantageous. The woods of silk oak and Hawaiian silkwood are fine grained and much lighter in color than those of the Eucalypts.

The D.P. of the cellulose is an important aspect in the considerations of potential use of a wood for pulping purposes. It was determined by a chemical procedure (*10*) which has been shown to give comparable results to other chemical or physical methods (*15*). The results of these determinations are summarized in Table II. The D.P. of the alpha-cellulose of loblolly- and slash pine, under the prevailing experimental conditions, compared favorably with the D.P. obtained for the alpha-cellulose preparations from Douglas-fir. In this respect, the two *Pinus* species introduced

Table II. The Average Molecular Size of the Alpha-Cellulose of the Various Woods

Species	$D.P._{no.\ av.}$ of alpha-cellulose	Molecular weight ($162 \times D.P._{no.\ av.}$)
1. *Cedrela odorata*	355	57,510
2. *Toona ciliata* var *australis*	450	72,900
3. *Eucalyptus robusta*	380	51,560
4. *E. saligna*	330	53,460
5. *E. citriodora*	400	64,800
6. *E. pilularis*	400	64,800
7. *Flindersia brayleyana*	480	77,760
8. *Grevillea robusta*	320	51,840
9. *Samanea saman*	370	59,940
10. *Fraxinus uhdei*	435	70,470
11. *Albizzia moluccana*	435	70,470
12. *Araucaria excelsa*	430	69,660
13. *Pinus caribaea*	550	89,100
14. *Pinus taeda*	530	85,860
15. *Pseudotsuga taxifolia*	520	84,240

should be useful as potential pulp sources. The D.P. of the alpha-cellulose of Norfolk Island pine was lower but probably not significantly so as to exclude this species from the above general category. Although the D.P. of the alpha-cellulose of Hawaiian silkwood is only slightly lower than the value found for Douglas-fir, the amount of cellulose present in the wood was found to be quite low and would probably be a limiting factor.

As might be expected, the woods from loblolly- and slash pine, Norfolk Island pine, and a few other species were considerably lighter or less dense than the woods from the Eucalyptus species. The densities of the various woods and the moisture content of the airdry sawdust samples from each are in Table III.

Of the four eucalyptus species examined, *Eucalyptus saligna* (blue gum) had the lowest density (0.86 g./cc.) while the wood of *Eucalyptus citriodora* (lemon gum) was heavier than water (1.05 g./cc.). The density of the wood from Spanish cedar and Australian red cedar was also rather high.

Where mechanical strength of the wood is not a deciding factor, e.g., pulp, some of the introduced tree species of Hawaii could assume considerable ecnomic importance. Loblolly- and slash pine and Norfolk Island pine show rapid growth even in the more arid regions of the Hawaiian Islands and their chemical composition suggests that they can, in the future, serve well in a pulping industry.

SUMMARY

Fifteen different forest tree species, of which 12 are presently recommended as saw timer trees for Hawaiian conditions, were analyzed for various constituents. Generally accepted chemical procedures were used. A chemical method which had previously been shown to give comparable results with those of other chemical or physical procedures was used in determining the $D.P._{no.\ av.}$ of the alpha-cellulose.

The extractives of Norfolk Island pine, slash- and loblolly pine were low and compared with the analytical value obtained for Douglas-fir. Some of the highly pigmented woods such as Spanish cedar, Australian red cedar (toona), and the Eucalypts were generally high in extractives. Silk oak (*Grevillea robusta*), a less pigmented wood, was also high in extractives.

The hemicellulose content of Norfolk Island pine, slash- and loblolly pine, and a few of the other species examined was low and in the general range found for Douglas-fir.

Only loblolly- and slash pine contained as much alpha-cellulose as did Douglas fir. Norfolk Island pine contained 4 to 5% less cellulose. All of the other species except Shamel ash (42%) contained less than 41% cellulose.

The molecular size of the alpha-cellulose from loblolly- and slash pine was comparable to that found for alpha-cellulose from Douglas-fir. The $D.P._{no.\ av.}$ of the alpha-cellulose from Norfolk Island pine was somewhat lower. The $D.P._{no.\ av.}$ of the alpha-cellulose from Hawaiian silkwood was quite high.

The lignin content of the various species varied from 20% (silk oak) to 32.5% for blue gum (*Eucalyptus saligna*). The Eucalyptus species were generally high in lignin as was Norfolk Island pine.

The woods from loblolly- and slash pine, Norfolk Island pine, Shamel ash, Albizzia, and Hawaiian silkwood had a density of 0.53 g./cc. or less. The density of woods from the Eucalyptus species was found to range from 0.86 to 1.05 g./cc.

Table III. The Moisture Content of Sawdust Samples and the Density of the Woods

Species	Moisture content, %	Density, g./cc.
Cedrela odorata	11.0	0.85
Toona ciliata var *australis*	9.8	0.70
Eucalyptus robusta	10.5	0.96
E. saligna	9.3	0.86
E. citriodora	10.8	1.05
E. pilularis	13.8	0.91
Flindersia brayleyana	10.0	0.53
Grevillea robusta	8.5	0.71
Samanea saman	8.5	0.68
Fraxinus uhdei	9.0	0.48
Albizzia moluccana	9.3	0.53
Araucaria excelsa	10.1	0.51
Pinus caribaea	9.0	0.47
Pinus taeda	9.3	0.47

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Chemical Composition and Physical Properties of Wood Fibers

I. Preparation of Holocellulose Fibers from Loblolly Pinewood

BENGT LEOPOLD

In an effort to develop a method for the preparation of virtually intact holocellulose fibers from loblolly pine, the chlorine-ethanolamine, chlorite, and peracetic acid holocellulose methods were compared with respect to yield, degradation, and degree of oxidation of the wood carbohydrates. It was found that the peracetic acid method, modified by a subsequent sodium borohydride step, gave a superior holocellulose with a D.P. of 3050–3600, 93–100% recovery of major polysaccharides and a minimum of carboxyl groups.

It is becoming increasingly apparent that the key to a real understanding of papermaking fundamentals in general, and sheet properties in particular, is a deeper and more complete knowledge of the fundamental properties of the individual fiber. Only through judicious development and use of such knowledge can we hope to build up a strong theoretical structure that will enable us to adequately explain the behavior of paper under various circumstances. Such basic understanding could then lead us in a direction toward paper products with improved characteristics and new, interesting properties.

The following is the first in a series of papers describing a study of the chemical and physical properties of individual wood fibers. A large portion of this series will be devoted to a thorough characterization of fibers—chemically, morphologically, and mechanically. In addition, attempts will be made to establish how individual fiber properties affect sheet properties and how these effects vary with chemical and mechanical processing of the fiber.

Since it can be assumed that even relatively small changes in the fiber, especially on the surface, would have a significant effect on its "papermaking" characteristics, it is essential that fibers be isolated from the wood with more than usual care. For this reason, a rather extensive comparative evaluation of a number of holocellulose methods was made, and the results of this work are given in this first article.

HOLOCELLULOSE METHODS

By far the most commonly used holocellulose method is the chlorite method, originally described by Jayme (*1*), but developed into its present-day form by Wise and co-workers (*2*). This method gives holocelluloses in near-quantitative yields in a relatively short time, but the results have been criticized by Timell, *et al.* (*3, 4*), who found that the chlorite method gives a more highly degraded product than does the chlorine-ethanolamine method introduced by Van Beckum and Ritter (*5*). The latter method has been adopted as a TAPPI Standard (*6*). A promising, but relatively new and less well-known method is the peracetic acid method, first described by Poljak (*7*), and further developed by Haas, Schoch, and Ströle (*8*). Other methods using nitric acid (*9, 10*), monoethanolamine (*11*), and hypochlorite (*12*) have been suggested, but have not won acceptance.

In the present work it was decided to confine the comparison to the chlorite, chlorine-ethanolamine, and peracetic acid methods. This comparison would be carried out using wood meal as a substrate (Series A). The most suitable of the three methods would then be selected, and used as basis for a technique for the preparation of fibrous holocellulose from wood chips (Series B).

MATERIALS AND METHODS

Wood

For Series A, the wood was obtained from a 10-in., 17-yr.-old log from Brunswick, Ga. Disks were cut, chipped, and ground in a Wiley mill to 35–65 mesh size. The wood meal was extracted with 2:1 ethanol-benzene.

For Series B, the wood was cut from an 8-in., 14-yr-old log, also from Brunswick, Ga. Chips approximately 25 × 10 × 1 mm. were cut from annual rings 10–12, care being taken that summerwood and springwood were separated. Any "intermediate" wood was discarded. The chips were extracted with 2:1 ethanol-benzene.

Analyses

Lignin, *methoxyl*, and *pentosan* analyses were carried out essentially according to TAPPI Standards (*13, 14, 15*).

Acetyl was determined using I.P.C. Method No. 19, (*16*).

Sugars were determined by paper chromatography. The method was a combination of that described by Saeman, *et al.* (*17*), and that of Timell and co-workers (*18*).

Carbonyl was determined by the hydroxylamine method described by Gladding and Purves (*19*). The same reference describes the calcium acetate method used for the *carboxyl* determination.

MOLECULAR WEIGHT DETERMINATIONS

Molecular weights were determined viscometrically in ethyl acetate, after nitration of the samples according to Mitchell and Alexander (*20*). In the case of wood, the nitration procedure described by Timell (*21, 22*) was

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Table I. Comparison of Holocelluloses

All Analytical Values on the Basis of the Weight of Original Extracted Wood

	Yield, %	Lignin, %	Acetyl, %	Carboxyl, meq./g.	Carbonyl, meq./g.	Glucan, %	Galactan, %	Mannan, %	Araban, %	Xylan, %	Pentosans, %	$[\eta]_{600}$, dl./g.	D.P.
Wood	100	28.5	1.7	0.20	0.15	46.3	1.6	10.4	1.1	6.9	7.9	56.3	4500
Chlorite holocellulose	74.8	3.2	1.3	0.40	0.01	45.0	1.4	10.2	0.8	6.6	7.5	28.5	2280
Chlorine–ethanolamine holocellulose	77.3	2.0	0.5	0.29	0.00	45.5	1.6	10.0	1.0	5.9	7.2	32.3	2580
Peracetic acid holocellulose	75.3	2.6	1.2	0.26	0.20	45.0	1.3	9.5	1.0	6.8	7.8	30.2	2420
Above reduced with $NaBH_4$	...	...	...	0.24	0.02	45.3	1.2	9.9	1.0	6.7	...	31.5	2530

used. In the calculation of intrinsic viscosities, the reduced viscosities were corrected for kinetic energy loss and differences in shear rate as described by Timell (*23*). D.P. values were calculated by multiplying intrinsic viscosities by 80.0.

RESULTS OF DELIGNIFICATION EXPERIMENTS

Wood Meal. Series A

For each of the three methods studied, a great number of preliminary runs were made under varying conditions. The results were evaluated by analyzing the residues for lignin, pentosan, and acetyl. In this way, it was possible to establish quickly the optimum conditions for each method, i.e., those conditions giving a maximum of delignification with a minimum of carbohydrate loss.

These conditions were:

Chlorite. Reagent and general procedure as described by Wise (*2*). Temperature 80°C. Six treatments of 1 hr. each.

Chlorine-ethanolamine. According to TAPPI Standard T 9 m-54. Seven treatments.

Peracetic acid. Five grams of peracetic acid and 2.5 g. of sodium acetate per gram of wood. Total volume 32 ml. per g. of wood. Temperature 70°C; reaction time 2 hr.

The samples obtained under these conditions were subjected to a thorough analysis, and the results are given in Table I.

It is evident that in all cases the retention of carbohydrates is good, with some loss of xylan occurring in the case of chlorine-ethanolamine, and of mannan in the case of peracetic acid. In terms of oxidative attack, the chlorite method seems to be the least desirable, as shown by the high carboxyl content and low D.P. of the chlorite holocellulose. Peracetic acid shows the lowest carboxyl content, but a very high carbonyl content. However, the latter could be eliminated by sodium borohydride reduction (3 hr., pH 9.5). The elimination of these carbonyl groups is essential, since they would have a profound effect on any subsequent work involving treatment or extraction with alkali, as shown in Table II.

Table II. Yield and D.P. of Alkali-Extracted Holocelluloses

26% KOH in nitrogen atmosphere

	Alkali-extracted holocellulose Yield, % based on wood	D.P.
Peracetic acid	50.8	1780
Peracetic acid–sodium borohydride	55.7	2270
Chlorite	54.6	2080
Chlorine-ethanolamine	54.7	2380

On the basis of the results in Table II, it was decided that the peracetic acid–sodium borohydride combination would best fulfill the requirements, and this method was used exclusively in Series B.

Wood Chips. Series B

A great number of preliminary runs were needed in order to develop a technique that would allow a reasonable degree of defiberization of the chips, essentially without mechanical treatment, and yet give a yield approaching the "optimum" established in Series A.

It was found that this could be achieved by modifying the standard procedure as follows:

1. The treatment was divided into a number of shorter cycles, consisting of a peracetic acid treatment followed by a soaking in hot water.
2. At the end of each cycle the chips were washed and the water removed with acetone. After air drying, the chips were then placed in a suction flask, the flask evacuated, and a new batch of reagent sucked into the chips.
3. At the conclusion of the sodium borohydride reduction, the delignified, soft chips were defiberized by gently rubbing against the wall of a glass beaker in the presence of hot water.

DISCUSSION

The only appreciable difference in carbohydrate composition between springwood and summerwood is that the summerwood contains more mannan than the springwood. This is in agreement with Meier's findings for Scots pine (*24*). On the other hand, no difference was observed in xylan content, such as had been shown by Meier.

The D.P. values for the wood are very close to those observed by Timell (*21, 22*) for other softwoods. An interesting observation is the fact that the summerwood preparations had a considerably higher D.P. than the springwood preparations. Since no appreciable differences existed in the wood, this must be caused by a greater susceptibility of the springwood to the attack of the reagent. This is probably a result of the difference in cell wall thickness, the thinner springwood wall providing better access of the reagent to the inner cell wall layers.

The results in Table III show that the fibrous holocellulose has a low degree of oxidation and a high retention of carbohydrate material. It compares favorably with the holocellulose prepared from wood meal, as shown by Table IV.

It is clear that the fibrous holocellulose is even less degraded than that from wood meal. It is also in-

Table III. Fibrous Holocellulose by the Peracetic Acid–Sodium Borohydride Method
Temperature, 80°C. Each cycle, 30 min. peracetic acid, 30 min. hot water

		No. of cycles	Yield, %	Lignin, %	Carboxyl, meq./g.	Carbonyl, meq./g.	Glucan, %	Galactan, %	Mannan, %	Araban, %	Xylan, %	$[\eta]_{500}$, dl./g.	D.P
Summerwood, 66% of total wood	Wood	...	100	27.4	0.23	0.17	46.9	1.6	11.0	0.7	6.4	57.5	4610
	Holocellulose	5	71.7	0.1	0.20	0.01	47.3	1.2	10.2	0.4	6.3	45.0	3600
Springwood, 34% of total wood	Wood	...	100	28.3	0.23	0.19	45.9	1.2	9.6	1.4	6.4	58.3	4670
	Holocellulose	3	75.2	1.5	0.22	0.01	46.4	0.5	9.4	0.5	6.2	38.1	3050

teresting to note that the retention of mannan and xylan is slightly better in the fibrous material, but losses of galactan and araban are higher. Both of these phenomena may be explained on the basis of the difference in accessibility to the various cell wall layers. Thus, in the wood meal preparation, the inner layers of the cell wall, containing a higher percentage of cellulose and glucomannan (*24*), are exposed to an oxidative or

Table IV. Comparison of Holocelluloses Prepared from Wood Chips and Wood Meal

Holocellulose	Yield, %	% Retention of— Glucan	Galactan	Mannan	Araban	Xylan	D.P.
From wood meal	75.3	99	80	91	88	94	2530
From wood chips							
Summerwood	71.7	100	72	93	50	99	3600
Springwood	75.2	100	50	97	40	99	3050

a hydrolytic attack, or both, by the reagent, resulting in a lower D.P. and mannan retention. In the fibrous material, on the other hand, the attack is primarily in the outer (primary) wall. There are strong indications that this layer contains a preponderance of pectic acid, galactan, and araban (*24*). This would, of course, explain the loss of galactan and araban.

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Chemical Composition and Physical Properties of Wood Fibers

II. Alkali Extraction of Holocellulose Fibers from Loblolly Pine

BENGT LEOPOLD

Peracetic acid holocellulose fibers from summerwood and springwood were subjected to a series of successive extractions with alkaline reagents of increasing swelling and dissolving power. The xylan-based polysaccharides were removed almost quantitatively with 1.5 *N* KOH, with the summerwood fibers showing a slightly higher resistance against extraction than the springwood fibers. The mannan-based polysaccharides were virtually untouched until 1.5 *N* KOH containing borate was employed. They were then gradually removed as the alkali concentration increased. Summerwood fibers still contained 44% of the mannan after the last extraction step (6 *N* NaOH), while only 17% remained in the springwood fibers.

In studies on the properties of polysaccharides in wood fibers, information regarding various characteristics of the different fiber components can conveniently be obtained by following the change in chemical composition occurring during alkaline extraction of the fiber. This general technique has been widely used, and the field has been reviewed recently by Nelson (*1*).

A number of workers have studied the extraction of nonfibrous holocellulose. Black spruce chlorite holo-

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Table I. Successive Extraction of Holocellulose Fibers

Code	*Extraction step*	*Remarks*
a	Original holocellulose	Peracetic acid–sodium borohydride
b	Dimethylsulfoxide (DMSO)	
c	Hot water	*ca.* 90°C.; two 2-hr. treatments
d	0.1 *N* KOH	
e	0.4 *N* KOH	
f	1.5 *N* KOH	
g	1.5 *N* KOH + 0.75 *M* H_3BO_3	
h	3.0 *N* KOH + 0.75 *M* H_3BO_3	
i	6.0 *N* KOH + 0.75 *M* H_3BO_3	
j	6.0 *N* NaOH	

cellulose was studied by Clermont (*2*), who showed that the hemicellulose could be divided into two categories, one more easily extracted with alkali and based largely on xylose, and one more resistant to extraction and based largely on mannose, and similar results have been found with other species (*1*, *3*). Ward and co-workers (*4*, *5*) showed that there are considerable differences in extracting power between KOH and NaOH, and that the order of extraction also is important. Jones, Wise, and Jappe (*6*) demonstrated that the addition of borate to the alkaline reagent greatly facilitates the removal of mannan. Hägglund, Lindberg, and McPherson (*7*) showed that the slightly alkaline solvent dimethylsulfoxide (DMSO) has a strong swelling action on chlorite holocellulose and that a considerable percentage of the hemicellulose can be extracted with this solvent and with a subsequent hot-water extraction.

In the present investigation the extractions were performed on fibrous holocellulose material, since it was felt that the results obtained would be more directly applicable to the behavior of fibers in various papermaking situations. This procedure would also provide a series of samples that would be very useful for further studies of the physical properties of fibers of varying composition.

Relatively few papers have been published on the effect of alkaline extraction on fibrous holocellulose. Of special interest here is a paper by Klauditz (*8*) in which he describes the extraction of chlorited wood blocks with sodium hydroxide, and determines the effect on chemical composition and strength properties. Mention should also be made of the work by Hamilton and Partlow (*9*), who extracted chlorite holocellulose from western red cedar chips with 18% sodium hydroxide, and studied the removed polysaccharide fractions.

EXPERIMENTAL

Holocelluloses. The fibrous peracetic acid holocellulose samples from loblolly pine summerwood and springwood were described in Part I of this series (*10*).

Extraction Sequence. The extraction procedure was designed so as to provide a gradual removal of the various polysaccharides. This was accomplished by the sequence given in Table I.

Unless otherwise stated, all extractions were carried out at room temperature, and consisted of one treatment overnight, followed by an identical treatment with fresh reagent, but for 7 hr. only. All extractions were conducted in nitrogen atmosphere.

The samples were washed thoroughly with water, 1% aqueous acetic acid, water, and stored wet in the refrigerator.

Analyses. Sugar determinations were carried out by a combination of the methods of Saeman, *et al.* (*11*), and Timell and co-workers (*12*). The molecular weights were measured viscometrically as described in Part I (*10*). D.P. values were obtained by multiplying intrinsic viscosity values (ethyl acetate) by 80.0.

RESULTS

Tables II and III show the variation in carbohydrate composition and D.P. on successive extraction. The carbohydrate values are given as sugar polymer in percentage of extracted wood.

On the basis of these data, the contents of those polysaccharides most likely to be present in the cell wall were calculated, essentially as suggested by Meier

Table II. Summerwood Series

Code	*Treatment*	*Yield, %*	*Glucan, %*	*Galactan, %*	*Mannan, %*	*Araban, %*	Xylan, %	$[\eta]_{500}$ *dl./g.*	*D.P.*
0	Wood	100.0	46.9	1.6	11.0	0.7	6.4	57.5	4610
a	Holocellulose	71.7	47.3	1.2	10.2	0.4	6.3	45.0	3600
b	DMSO[a]	70.7	47.7	1.1	9.2	0.1	6.2	...	...
c	Hot water	68.5	47.0	0.7	9.4	0.0	5.9	40.6	3240
d	0.1 *N* KOH	64.5	46.3	0.0	9.2	0	5.8	...	...
e	0.4 *N* KOH	62.8	46.1	0	8.9	0	4.8	...	...
f	1.5 *N* KOH	57.3	46.5	0	9.0	0	0.9	41.3	3300
g	1.5 *N* KOH + 0.75 *M* H_3BO_3	52.8	44.7	0	7.4	0	0.8	32.8	2620
h	3.0 *N* KOH + 0.75 *M* H_3BO_3	51.7	44.2	0	6.0	0	0.5	29.1	2330
i	6.0 *N* KOH + 0.75 *M* H_3BO_3	50.3	43.5	0	5.0	0	0.1	...	...
j	6.0 *N* NaOH	49.3	43.2	0	4.8	0	0.0	20.7	1650

[a] Dimethylsulfoxide

Table III. Springwood Series

Code	*Treatment*	*Yield, %*	*Glucan, %*	*Galactan, %*	*Mannan, %*	*Araban, %*	*Xylan, %*	$[\eta]_{500}$ *dl./g.*	*D.P.*
0	Wood	100.0	45.9	1.2	9.6	1.4	6.4	58.3	4670
a	Holocellulose	75.2	46.4	0.5	9.4	0.5	6.2	38.1	3050
b	DMSO[a]	74.0	46.7	0.2	8.6	0.1	6.0	...	...
c	Hot water	71.7	47.8	0.3	8.9	0.2	5.5	35.7	2860
d	0.1 *N* KOH	67.1	47.2	0.0	8.6	0.0	5.2	...	...
e	0.4 *N* KOH	64.9	47.5	0	8.3	0	3.6	...	...
f	1.5 *N* KOH	61.8	47.0	0	7.9	0	0.8	32.7	2610
g	1.5 *N* KOH + 0.75 *M* H_3BO_3	48.6	45.8	0	3.1	0	0.5	27.3	2180
h	3.0 *N* KOH + 0.75 *M* H_3BO_3	47.1	44.2	0	2.6	0	0.1	24.3	1940
i	6.0 *N* KOH + 0.75 *M* H_3BO_3	46.2	43.2	0	2.0	0	0.0	...	...
j	6.0 *N* NaOH	44.4	42.5	0	1.5	0	0	15.9	1270

[a] Dimethylsulfoxide.

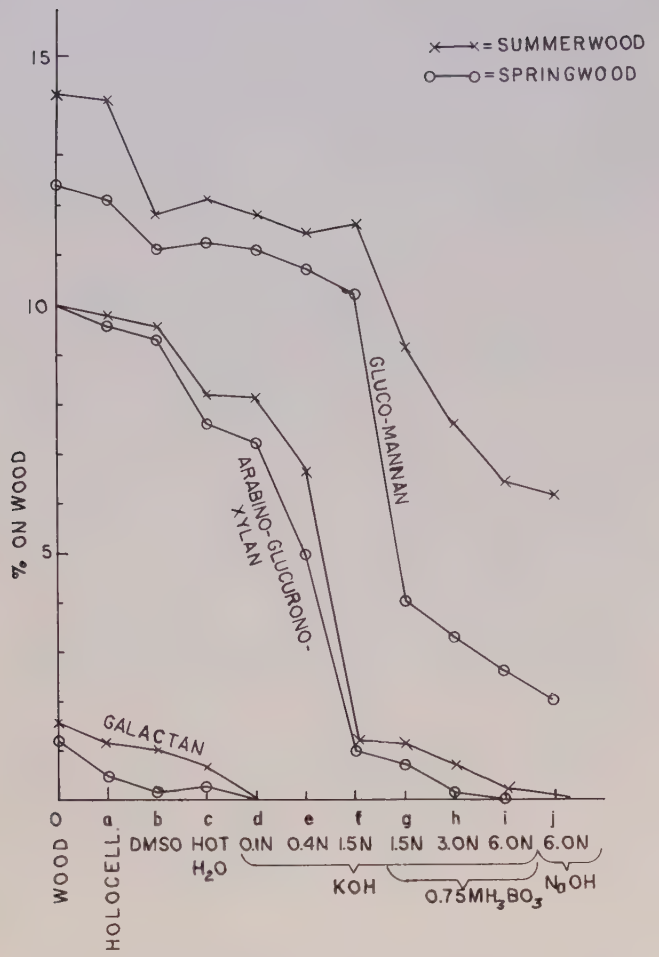

Fig. 1. Removal of polysaccharide components on extraction of holocellulose fibers

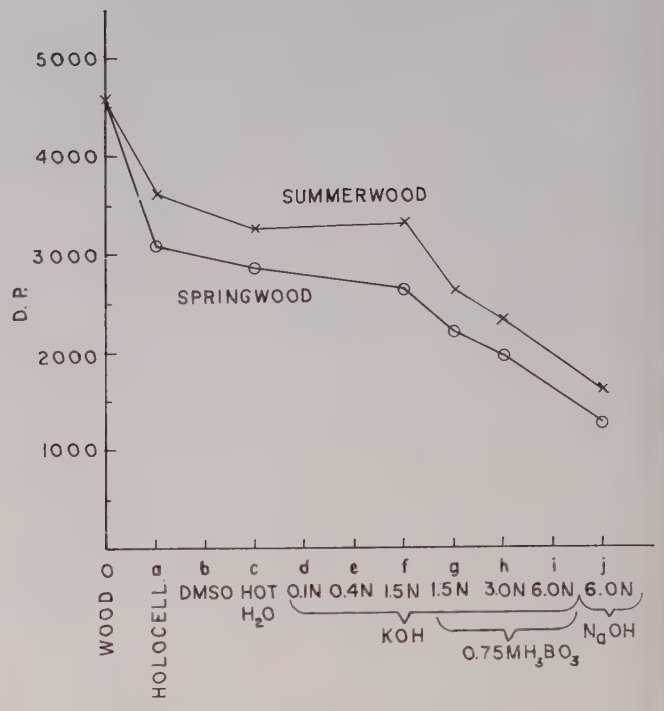

Fig. 2. Change in D.P. on extraction of holocellulose fibers

(*13*). It was assumed that the glucomannan has a glucose:mannose ratio of 1:3.5 and the arabino-glucurono-xylan an arabinose:glucuronic acid:xylose ratio of 1:2.5:9. The glucan not in the glucomannan was considered to be cellulose. The latter figure was reasonably constant for all samples and averaged 43.4% for summerwood and 43.9% for springwood.

Figure 1 shows the contents of polysaccharides as a percentage of the weight of the original wood, plotted against number of extraction steps. Figure 2 shows the concurrent change in D.P.

DISCUSSION

Figure 1 confirms previous results (*1*, *2*, *3*) that different polysaccharides are removed during different stages of the extraction sequence, and three distinct stages may be observed.

In the first stage, which comprises extraction with DMSO, hot water and very dilute alkali, all the galactan is removed. This is easily understood, since most of the galactan-containing polysaccharides are known to be located in the outside cell-wall layers (*14*, *15*). A gradual removal of xylan-based material is also observed during this stage. In addition, 8% of the total glucomannan is extracted in the DMSO stage, but no further extraction seems to occur with hot water or alkali up to 1.5 *N*. This does not agree with observations made by Lindberg and Meier (*16*), who found that a hot water extraction following a DMSO treatment of spruce chlorite holocellulose removed 10 to 15% of the mannan-based polysaccharides. This discrepancy may possibly originate in the fact that the present work was done with fibrous holocellulose which is presumably less easily penetrated by the hot water. Also, the fibrous holocellulose used in this work would be less degraded than that from wood meal, particularly since it was prepared by the peracetic acid–sodium borohydride method described in Part I of this series (*10*).

In the second stage, which comprises extractions with 0.4 *N* and 1.5 *N* KOH, almost all of the xylan-based polysaccharides are removed. Summerwood and springwood preparations show a similar pattern, with the rate of extraction of the springwood slightly higher.

In the third stage, which comprises extraction with KOH of increasing concentration, in the presence of borate, the glucomannan is removed preferentially. These results agree very well with those obtained by Lindberg and Meier in their comprehensive study on spruce chlorite holocellulose (*16*).

One novel feature shown here is the remarkable difference in the behavior of springwood and summerwood. Thus, only 17% of the glucomannan in the springwood remains after the final extraction step, while the corresponding figure for summerwood is 44%. The curves in Fig. 1 indicate that a much greater percentage of the springwood glucomannan is extracted in the first borate step, *g*, and that the subsequent relative rate of extraction is equal to or even lower than that of the summerwood mannan.

The most plausible explanation for this phenomenon can be based on the difference in morphological structure of the two types of fibers. The springwood fiber wall is much thinner than the summerwood fiber wall and the former contains a lower percentage of the middle layer of the secondary wall (*17*). If it is assumed that this layer (S_2) is the most highly ordered (least accessible) layer in the cell wall, the glucomannan located in this layer would be more difficult to remove

than glucomannan located elsewhere. Then, since the springwood fiber contains a higher proportion of accessible layers, it would contain a higher proportion of more easily extractable glucomannan.

An alternative, less likely, explanation would simply be that the springwood fiber wall *as a whole* would be more easily accessible because it is thinner. However, if this were the case, one would expect the rate of extraction of glucomannan from the springwood fibers to be greater during *all* stages of the extraction, rather than in one specific step.

Figure 2 shows that the D.P. values of the preparations drop only very slightly during the first five extraction steps, and then a sudden drop takes place in step *g*, to be followed by similar drops in steps *h* to *j*. A comparison of springwood and summerwood shows that the difference in D.P. between the holocellulose samples is maintained throughout the extraction sequence. This means that the degradation is not appreciably affected by differences in cell wall thickness, etc.

The above observations are most easily explained by assuming that the drop in D.P. is caused by oxidation by traces of oxygen present, in spite of the nitrogen purge. Appreciable degradation takes place only after sufficient swelling has occurred, but from then on the rate is determined only by the small quantity of oxygen present and is essentially independent of the alkali concentration.

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Chemical Composition and Physical Properties of Wood Fibers

III. Tensile Strength of Individual Fibers From Alkali Extracted Loblolly Pine Holocellulose

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A convenient and relatively speedy technique for directly measuring the tensile strength and cross-sectional area of individual fibers is described. Strength and cross-sectional area of individual summerwood and springwood holocellulose fibers decrease as the fibers are progressively extracted with alkali of increasing concentration. Reduction in individual summerwood and springwood fiber strength shows a correlation with removal of xylan-based hemicellulose. No correlation is evident between fiber strength and change in D.P. or glucomannan content. Summerwood fibers are about twice as strong per unit cross-sectional area as springwood fibers. It is suggested that morphological differences between the two types of fibers are responsible for the difference in strength.

In any attempt to relate the properties of individual fibers to the strength of a sheet of paper, two major factors have to be considered, fiber-to-fiber adhesion and individual fiber strength. The former is governed by such parameters as bonding potential and area of exposed fiber surfaces, flexibility and plasticity of the fibers, and the general geometry of the sheet. Fiber strength, on the other hand, depends generally on the internal structure of the fiber, such as fibrillar orientation and cohesion, and on external factors, such as flaws and irregularities in the fiber wall, and the general morphology of the fiber.

Optimum paper strength is achieved when a critical balance exists between fiber-to-fiber adhesion and individual fiber strength. Thus, if the sheet is made of strong fibers but with insufficient bonding, fiber separation will occur and the strength potential of the individual fibers is not realized. Again, if a sheet is made of well-bonded but weak fibers, fiber failure will occur at the zone of rupture, and only part of the bonding potential is utilized.

Very little published information is available on the contribution of individual fiber strength to tensile strength of paper. Work by Van den Akker, *et al.* (*1*), showed that a substantial number of fibers fail when paper is broken in tension. Microscopic work in this laboratory has also shown that numerous fibers break at the zone of rupture when paper fails in tension, both during standard tensile strength tests and when paper is folded.

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In spite of the growing realization that individual fiber strength is an important factor governing sheet strength, published data are very scarce. The reason for this is undoubtedly the experimental difficulties involved, due to the small size of the individual fiber. The main obstacles are the attachment of the fiber to a tensile tester and the determination of the cross-sectional area of the fiber wall at the zone of rupture.

An early attempt at direct measurement of single fiber strength was described by Wardrop (*2*) who glued his fibers to fine silk threads attached to a tester. Van den Akker (*1*) made use of paper tabs for attachment of the fiber, and relied upon measurement of external maximum and minimum diameters for an estimation of the cross-sectional area of the fiber wall. This method assumes a collapsed fiber lumen and an elliptical cross-sectional shape of the fiber V. Neither of these assumptions is valid for the fibers discussed below. Jayne (*3*) used pin vises for mechanically clamping fibers in a tensile testing instrument. His method of estimating cross-sectional area of the fiber wall was by viewing the fiber "end-on" at the break at 1000 × magnification and determining the cross-sectional area with an ocular micrometer. High magnification of such an object in air gives extremely poor resolution, so that measurements made in this manner give only an estimate of the fiber wall area. The splintered break of many of the fibers is also a severe drawback to this method.

To avoid what appears to be a tedious task of measuring fiber strength and cross-sectional area of single fibers, Van den Akker (*1*) developed the use of the so-called zero-span tensile strength test, originally proposed by Hoffman Jacobsen (*4*), as a means of measuring individual fiber strength. The assumptions made in calculating this suggested relationship between zero-span values and fiber strength—such as neglecting the influence of fiber-to-fiber bonding and introducing a factor to eliminate the effect of fiber orientation—have been the source of doubts as to the ability of the test to give a true picture of individual fiber strength. This has recently been elaborated upon by Stone and Clayton (*5*).

It is evident from the above that there is a need for a good method for individual fiber strength determination. The present report describes a method that allows convenient and relatively speedy measurement of the breaking load of a single fiber as well as its cross-sectional area, measured on cross sections cut as near as possible to the break. No unusual difficulty has been found in manipulating or testing single fibers or in the preparation and measurement of cross sections. Since the methods are direct, no assumptions must be made, no computations from indirect data are involved.

This method was used in a program designed to study the relation between chemical composition of fibers and their breaking strength. This was done by following the change in tensile strength of holocellulose fibers from loblolly pine, progressively extracted with alkali of increasing concentration. The chemical changes occurring during the same series of extractions were described in Part II of this series (*6*).

EXPERIMENTAL

Individual Fiber Strength

Fibers to be tested are taken at random from a dilute aqueous suspension of the sample while being observed at 25 × magnification. Each fiber is then mounted in a fiber assembly in the following manner:

The fiber, handled at its end by jewler's forceps, is placed across the narrow ends of two wedge-shaped paper tabs held in a specially modified spring clamp. Each end of the fiber is then glued to the tabs by applying a drop of Duco cement (colored cement is used to show its distribution on the fiber). The fiber assembly is then conditioned at 50% R. H. and 75°F. overnight and tested the next day at these atmospheric conditions.

The fiber assembly is attached to two fine jeweler's chains via small hooks inserted through holes in each tab. These chains are then fastened to the tensile testing device (see below), and the spring clamp is released. With this arrangement, the fiber is automatically aligned in the direction of the applied load, and all danger of failure through shear or twisting is eliminated.

The testing device used in this work is somewhat similar in principle to that used by Wardrop (*2*), and consists of a modified analytical balance. One chain of the fiber assembly is attached to one end of the balance arm and the other chain to the balance platform. A 100-ml. aluminum beaker is attached to the other end of the balance arm and counterbalanced. Load is applied to the fiber by admitting water to the beaker at a rate of 60 ml. per min. The quantity of water admitted at the time of break is recorded.

It should be pointed out that the fiber assembly described here can be used in any tensile strength tester. In the present work, a comparison was made between results obtained with the tester described above and those obtained with an Instron TT-C (Instron Engineering Corp. Canton, Mass.) No significant difference was found.

Cross-Sectional Area

The cross-sectional area of fibers broken in tension was measured on projected photomicrographs of cross sections cut as close to the break as possible. The broken fibers were embedded in cellulose acetate and cross sections cut on a microtome. Photomicrographs were made on 35-mm. film using a Leica camera and a Leitz Ortholux microscope fitted with a 100× oil immersion objective. Images of the cross sections on film were projected and traced at a total magnification of 3500×. Area of the lumen and fiber wall was then measured on the tracing with a planimeter.

Fibers Tested

For the purpose of developing the testing method, a great number of fibers of loblolly pine springwood and summerwood chlorite holocellulose was tested in tension and cross sectioned.

The work on the relation between chemical composition and tensile strength was done with a series of fiber samples obtained by progressive extraction, with alkali of increasing concentration, of springwood and summerwood holocellulose, prepared by the peracetic acid–sodium borohydride method described in Part I (*7*).

Reliability of the Method

It was found that about 50% of the fibers broke in the center span between the points of contact with the

Table I. Statistical Comparison of Fibers Broken in the Span and at the Glue-Line

Loblolly pine summerwood peracetic acid holocellulose

	Fibers broken in the center span	*t-value*	*Fibers broken at the glue-line*
No. of fibers	48	...	48
Individual fiber strength g./fiber	52	0	52
Cell-wall area, μ^2	608	1.89	565
Strength per unit area, kg./mm.^{2}	87	1.54 $t_{0.05} = 1.99$	93

adhesive, while the remainder broke close to, or at, the glue line. Table I shows that there is no significant difference in individual fiber strength, cross-sectional area of the fiber wall, or fiber strength per unit area, between fibers breaking at the glue line and fibers breaking in the center span. Therefore, data for fibers breaking in both of these locations were averaged.

This finding should be compared to information published by Stone and Clayton (*5*) which indicates, without supporting data, that use of mechanical means, such as pin vises, for gripping the fibers at both ends during tensile testing produces many fiber failures at the point of attachment, and that the data from such fibers must be rejected. It would be expected, certainly, that the pressures exerted on fibers by mechanical attachment, necessary to prevent fiber slippage when an axial load of as high as 80 or 90 g. is applied, must compress and damage the fiber and present an area of stress accumulation.

Jayne (*3*), on the other hand, states that when fibers were glued to fine wire, failure nearly always occurred at the point of bonding and offers as one explanation the possible eccentricity of the load on the fiber. His investigations, in which pin vises were used for attachment of the fibers, reportedly produced breakage of about 50% of the fibers at the grip. Jayne assumes, however, that stress concentrations produced by mechanical attachment are not of sufficient magnitude to materially influence the mechanical properties of wood fibers in tension.

It is felt that in the present study, the use of fine jeweler's chains for attachment of the paper tabs which support the fibers has eliminated the eccentricity of load, referred to by Jayne, and is thus instrumental in eliminating any significant difference in strength between fibers breaking in the center span and those failing near the glue line.

Table II. Fiducial Limits of Typical Groups of Fibers at the 95% Confidence Level

	Individual fiber strength, g.	*Cross-sectional area, μ^2*	*Fiber strength, kg./mm.^{2}*
Summerwood			
Mean	48	550	89
Fiducial limits	43–53	498–602	81–97
Springwood			
Mean	17	386	46
Fiducial limits	14–20	345–427	39–51

It was found that tensile testing of approximately 20 fibers chosen at random from one sample is sufficient to set fiducial limits on the mean strength and area of summerwood fibers of $\pm 10\%$ at the 95% confidence level and approximately $\pm 15\%$ on data for springwood fibers. This is illustrated in Table II.

In order to verify the fact that a relatively firm average can be obtained from a small group of fibers, at least 2 groups of 20 fibers each were taken at random from several samples and tested. Average fiber strength between groups of the same sample was found to vary never more than 8%, and statistical analysis always showed the difference to be not significant. For these reasons, the number of fibers tested from one particular sample in this laboratory has been standardized at approximately 20. The total working time required to mount 20 fibers for testing, to prepare cross sections and to determine cross-sectional area is about 10 hr.

RESULTS

Data on individual fiber strength, cross-sectional area of the fiber wall, strength of fibers per unit area, and yield are shown in Table III and Figs. 1 to 5.

Individual Fiber Strength

The strength of individual fibers of summerwood and springwood peracetic acid holocellulose was found to be similar to that of summerwood and springwood chlorite holocellulose, respectively. The fact that the strengths were similar was rather unexpected since the

Table III. Tensile Strength and Cross-Sectional Area of Unextracted and Alkali Extracted Holocellulose Fibers

Code	*Treatment*	*Individual fiber strength g./fiber*	*Cross sectional area, μ^2*	*Fiber strength per unit area, kg./mm.^{2}*	*Yield, %*	
					Based on holocellulose	*Based on wood*
		Summerwood				
	Chlorite holocellulose	51	504	102	...	60.8
a	Peracetic acid holocellulose	50	568	88	100	71.7
b	Dimethylsulfoxide	56	679	84	98.6	70.7
d	0.1 *N* KOH	54	596	92	90.0	64.5
e	0.4 *N* KOH	53	540	97	87.6	62.8
f	1.5 *N* KOH	34	483	70	80.0	57.3
h	3.0 *N* KOH + 0.75 *M* H_3BO_3	31	464	68	72.0	51.7
j	6.0 *N* NaOH	30	479	64	68.7	49.3
		Springwood				
	Chlorite holocellulose	15	322	48	...	58.3
a	Peracetic acid holocellulose	17	386	46	100	75.2
b	Dimethylsulfoxide	15	427	34	98.5	74.0
d	0.1 *N* KOH	13	340	39	89.2	67.1
e	0.4 *N* KOH	14	313	47	86.3	64.9
f	1.5 *N* KOH	11	334	34	82.3	61.8
g	1.5 *N* KOH + 0.75 *M* H_3BO_3	10	274	35	64.7	48.6
h	3.0 *N* KOH + 0.75 *M* H_3BO_3	7	260	27	62.7	47.1
j	6.0 *N* NaOH	7	277	28	59.4	44.4

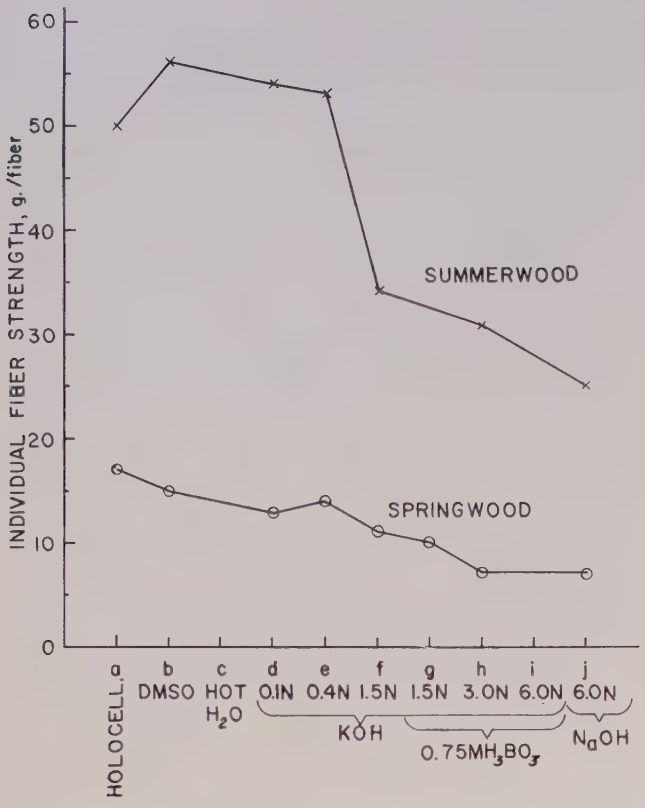

Fig. 1. Individual fiber strength vs. alkali concentration

yields of chlorite holocellulose were low, indicating more severe chemical attack.

Treatment of fibers with dimethylsulfoxide and alkali of low concentration did not change the individual fiber strength. Statistical analysis showed that the slight increase shown in Fig. 1 for summerwood is not significant.

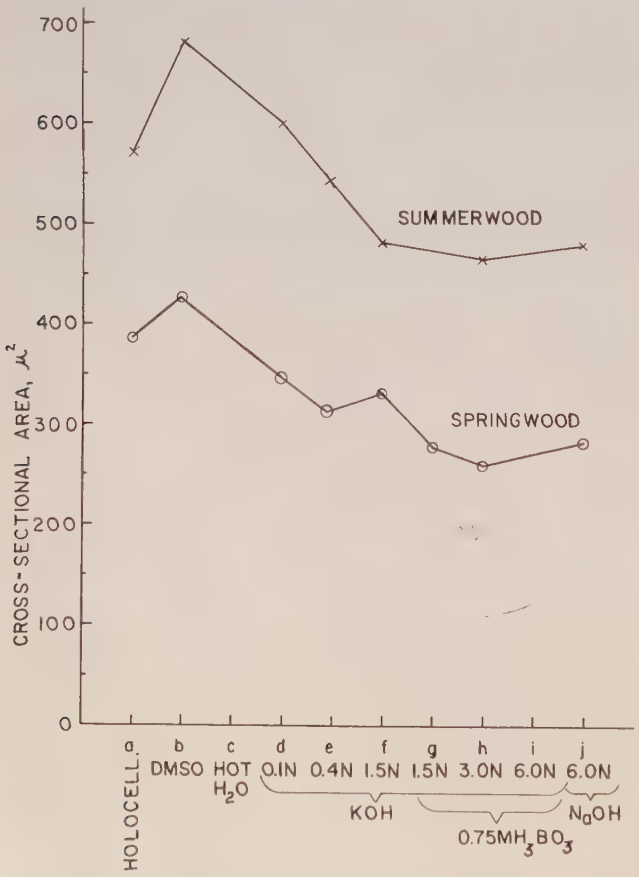

Fig. 2. Cross-sectional area of fiber wall vs. alkali concentration

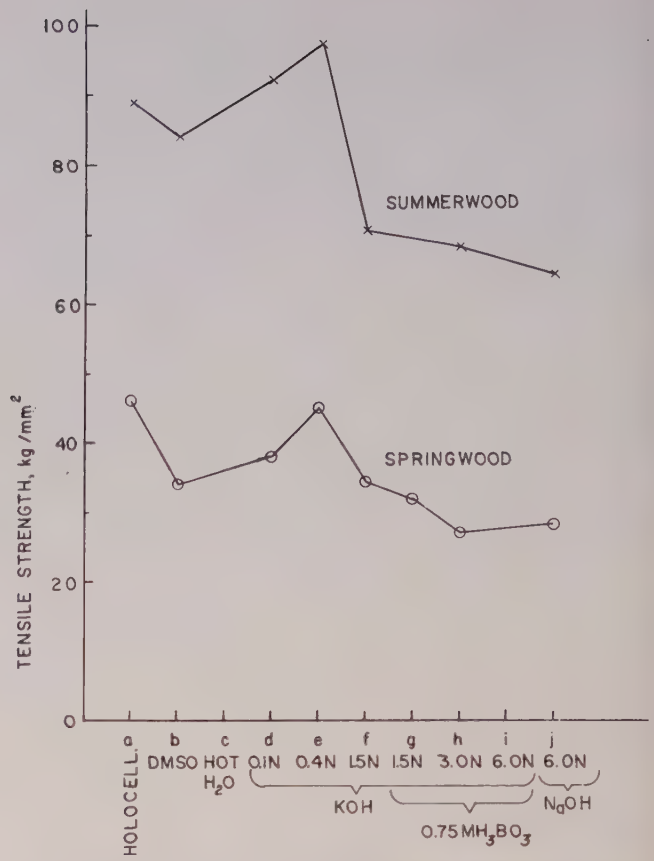

Fig. 3. Fiber strength per unit area vs. alkali concentration

Extraction with 1.5 *N* KOH caused a large decrease

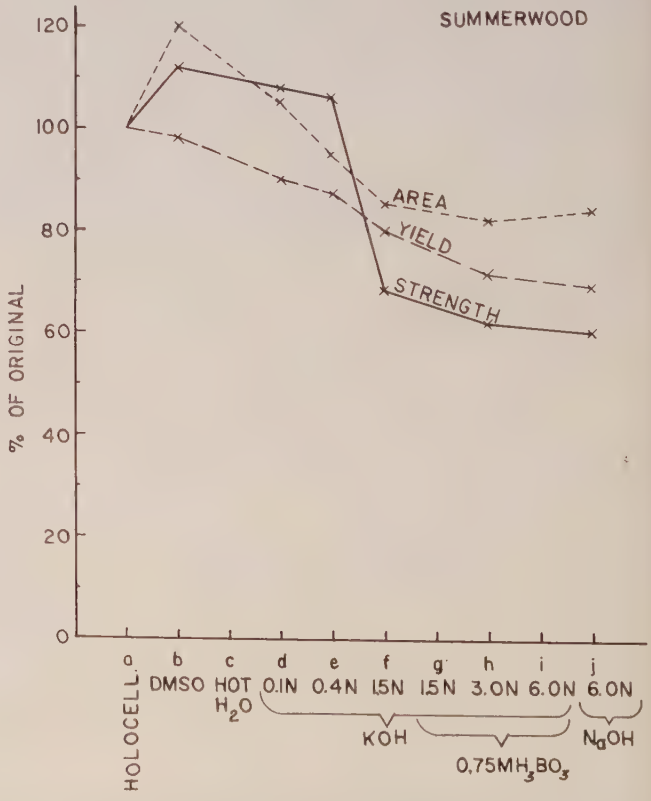

Fig. 4. Per cent change in individual fiber strength, cross-sectional area, and yield vs. alkali concentration

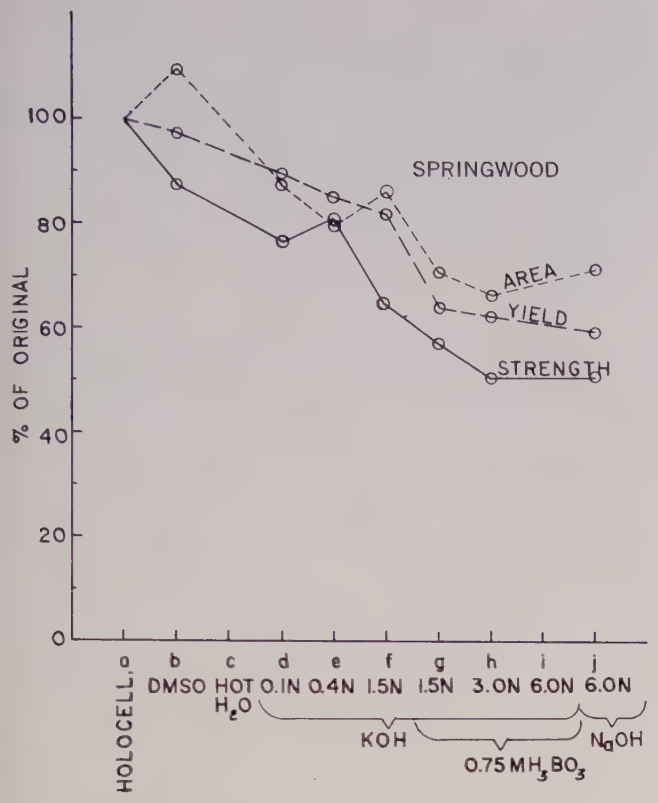

Fig. 5. Per cent change in individual fiber strength, cross-sectional area, and yield vs. alkali concentration

in strength of summerwood fibers. Extraction with increasing concentrations of alkali then produced only minor reductions in strength. Springwood fibers, on the other hand, showed a more gradual loss in strength upon extraction with alkali of increasing concentration.

This comparison can be seen more clearly in Figs. 4 and 5 which show the effect of extraction with different alkali concentrations on strength of individual fibers, expressed as a percentage of the original strength. It will be noted that after the final extraction, the strength of the summerwood fibers was 60% of that of the original unextracted fibers, while, with springwood fibers, only about 40% of the original fiber strength was retained.

Cross-Sectional Area of the Fiber Wall

Table III shows that the cross-sectional area of summerwood and springwood peracetic acid holocellulose is larger than that of summerwood and springwood chlorite holocellulose, respectively. This was expected since past results have indicated that cross-sectional area is related to yield. This relationship is also evident in Figs. 4 and 5, which show a close symmetry of the curves giving the yield and area (in per cent of the original), beginning with the first alkali extraction.

Treatment of summerwood and springwood peracetic acid holocellulose with dimethylsulfoxide increased the cross-sectional area of the fiber walls, as shown in Fig. 2. When the fibers were extracted with alkali, the cell-wall area decreased, abruptly at lower concentrations of alkali and then more gradually with increasing alkali concentration. The similarity of the curves for cell wall area of summerwood and springwood in Fig. 2 is striking.

Fiber Strength per Unit Area

Both summerwood and springwood fibers showed a decrease in strength when treated with dimethylsulfoxide. This apparent decrease in strength is caused by the swelling of the fiber walls, since individual fiber strength in grams per fiber was generally maintained. On the other hand, fiber strength per unit area increased after extraction with up to 0.4 *N* KOH since, the cell-wall area decreased but fiber strength, in grams per fiber, showed little change.

Summerwood and springwood fibers showed a large decrease in strength per unit area when extracted with 1.5 *N* KOH, as shown in Fig. 3. From then on, increase in alkali concentration had a minor effect on strength of summerwood fibers, while springwood fibers showed a further decrease in strength when extracted with 3.0 *N* KOH.

DISCUSSION

It will be noted that the strength per unit area of summerwood fibers is roughly twice the strength of springwood fibers and that this difference continues

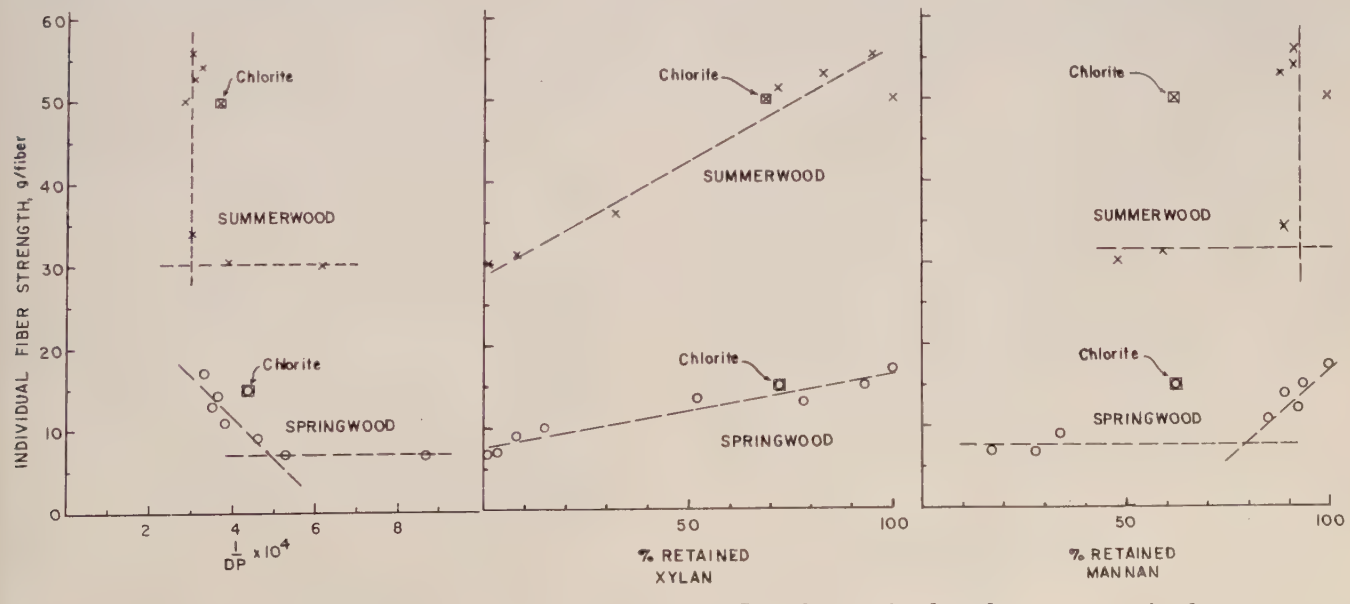

Fig. 6–8. Individual fiber strength vs. change in D.P., xylan retained, and mannan retained

throughout the alkali extraction series. This superior strength for summerwood fibers has been reported previously for Douglas-fir and cypress by Jayne (*3*). There is no substantial difference chemically or in D.P. between the two types of fibers which could cause such a large difference in strength. Morphological features of springwood fibers, such as well-developed bordered pits and cross-field pits, and the relatively low proportion of the springwood fiber wall composed of the middle layer of the secondary wall (S_2 layer) in which the fibril orientation is more nearly axial than in the other wall layers, are the suspected reasons for the difference in strength.

Work is now being carried out on the stressing of fibers while observing them at high magnification to note their reaction to applied stress and to observe the anatomy of the break which occurs on failure.

The most important finding presented here is undoubtedly the reduction in individual fiber strength caused by alkali extraction, because it may actually throw new light on the factors governing the internal cohesion in fibers, as seen from the discussion below. In this discussion, an attempt is made to find the most likely cause for the strength drop by examining three factors, viz., reduction in molecular weight of the cellulose, change in internal structure of the fibrils, and the effect of hemicelluloses.

Reduction in Molecular Weight of the Cellulose

Figure 6 is a plot of fiber strength against the reciprocal D.P. The reciprocal D.P. was used since tensile strength of rayon fibers has been shown to be a straight line function of 1/D.P. (*8*). No correlation appears to exist between individual fiber strength and 1/D.P. in the present study.

Change in Internal Structure of the Fibrils

The spatial relationship between cellulose molecules undergoes a major change during mercerization when the crystalline lattice type is changed, but only limited intercrystalline swelling takes place in alkali below mercerizing concentration. The minimum alkali concentration required for mercerization varies for different types of cellulose (*9*, *10*) but is generally 2 *N* or higher at room temperature. It is therefore unlikely that mercerization is responsible for the drop in fiber strength. However, further work is needed to establish this point.

Effect of Hemicelluloses

The carbohydrate analyses given in Part II (*6*) show that an abrupt drop in xylan content coincides with the drop in strength. The relationship between fiber strength and percentage of xylan-based hemicellulose retained in the fibers is shown in Fig. 7 for summerwood and springwood. Included in the graph are data for unextracted loblolly pine chlorite holocellulose. It will be seen that a linear correlation exists between strength and xylan-based hemicellulose content. On the other hand, there appears to be no correlation between individual fiber strength and glucomannan content (Fig. 8).

It should be mentioned that Klauditz (*11*) found a similar drop in tensile strength of delignified wood sections on extraction with 5% NaOH, but he attributed this strength reduction entirely to a weakening in fiber-to-fiber adhesion, and assumed that individual fiber strength is not affected by alkali extraction. Stone and Clayton (*5*), on the other hand, showed that the zero-span tensile strength of kraft-cooked sections, based on α-cellulose content, decreases with decreased yield, indicating that other factors besides cellulose content are involved. However, they claim that the hemicellulose content has little or no effect on fiber strength.

CONCLUSIONS

The reason for the results obtained in the present study is not known, but the following is offered as a tentative explanation. It is reasonable to assume that the adhesive forces between fibrils are weaker than the internal forces within the well-ordered fibril. Therefore, a fiber tends to rupture by separation of fibrils. If the xylan-based hemicellulose is largely located between fibrils, its removal would probably reduce the adhesion between fibrils and thus the internal strength of the fiber would drop. On the other hand, removal of the glucomannan would affect mainly the internal structure of the fibril, and this would have less effect on fiber strength. Recent results by Nelson (*12*) lend some support to these ideas. Among other things, Nelson followed the width of the (002) x-ray diffraction peak during extraction of slash pine chlorite holocellulose with increasing concentrations of alkali. He found that a marked drop in peak width occurred simultaneously with the removal of mannan, while the removal of xylan had little or no effect. These results indicate that at least part of the mannan is located in close association with the cellulose, since its removal facilitates the attainment of a higher degree of order of the cellulose molecules. The xylan, on the other hand, is probably located on the outside of the fibrils and between them.

If the above explanation is correct, it would mean that the hemicellulose content of a fiber is important for its internal strength as well as its ability to bond to other fibers in a paper sheet. In turn, this would mean that one of the major factors determining sheet characteristics is the carbohydrate composition of the pulp fiber, not only of its surface layer but also of the interior of the fiber wall.

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Received Dec. 6, 1960.

The authors are indebted to Dale B. Uhrig who tested the fibers in tension and determined the cross-sectional area of the fiber walls.

ASSOCIATION NEWS AND EVENTS

National Conferences

1961

Twelfth Coating Conference, May 8–10, 1961, Statler-Hilton Hotel, Buffalo, N. Y.

ISA-TAPPI Symposium on Instrumentation in the Pulp and Paper Industry, May 10–12, 1961, Northland Hotel, Greenbay, Wis.

10th Statistics Course, June 17–30, Queens Univ., Kingston, Ontario.

Lignin Symposium, Aug. 14–16, 1961, Edgewater Beach Hotel, Chicago, Ill.

Twelfth Testing Conference, Aug. 15–18, 1961, Queen Elizabeth Hotel, Montreal, Que.

Eleventh Corrugated Containers Conference, Sept. 6–8, 1961, St. Francis Hotel, San Francisco, Calif.

Fourth International Mechanical Pulping Conference, Sept. 19–21, 1961, Edgewater Beach Hotel, Chicago, Ill.

6th Deinking Conference, Oct. 4–6, 1961, Hotel Harris, Kalamazoo, Mich.

Sixteenth Plastics-Paper Conference, Oct. 9–11, 1961, French Lick Sheraton Hotel, French Lick, Ind.

Sixth Engineering Conference, Oct. 15–19, 1961, Shoreham, Hotel, Washington, D. C.

Fifteenth Alkaline Pulping Conference, Nov. 1–3, 1961, Rice Hotel, Houston, Tex.

1962

47th Annual Meeting, Feb. 18–22, 1962, Commodore Hotel, New York, N. Y.

Thirteenth Coating Conference, May 14–16, 1962, Netherland-Hilton Hotel, Cincinnati, Ohio.

Thirteenth Testing Conference, Sept. 18–20, 1962, Benjamin Franklin Hotel, Philadelphia, Pa.

Seventeenth Engineering Conference, Oct. 14–19, 1962, Queen Elizabeth Hotel, Montreal, Que.

Twelfth Corrugated Containers Conference, Oct. 23–26, 1962, Statler-Hilton Hotel, Boston, Mass.

Sixteenth Alkaline Pulping Conference, Oct. 31, Nov. 1–2, 1962, DeSoto Hotel, Savannah, Ga.

1963

Fourteenth Coating Conference, May 19–22, 1963, Concord Hotel, Kiamesha Lake, N. Y.

Thirteenth Corrugated Containers Conference, Oct. 22–25, 1963, Statler-Hilton Hotel, Detroit, Mich.

Eighteenth Engineering Conference, Oct. 28–31, 1963, Netherland Hilton Hotel, Cincinnati, Ohio.

Other Associations

The German Association, Verein der Zellstoff und Papier Chemiker und Ingenieure, will hold its annual meeting in Baden-Baden, June 27–30, 1961.

The 4th DRUPA-International Fair Print and Paper will be held at Dusseldorf, May 5–18, 1962.

The Eleventh National Chemical Exposition, sponsored by the Chicago Section, American Chemical Society, International Amphitheatre, Chicago, Ill., Sept. 5–8, 1961.

The Thirteenth International Chemical Engineering Exposition and Congress, Frankfurt am Main, Germany, June 9–17, 1961.

Twelfth Coating Conference

The Twelfth Coating Conference will be held at the Statler-Hilton Hotel, Buffalo, N. Y., Monday, May 8, through Wednesday, May 10, 1961.

Buffalo is located on Lake Erie at the source of the Niagara River. It is the second largest city in New York State and is the focal point of a great historical and scenic area known as the Niagara Frontier. Buffalo is the threshold of Niagara Falls and the Gateway to Canada. Being the fourteenth largest city in the United States, its metropolitan facilities offer home comfort, convenience, and easy access to every interesting point throughout the renowned Niagara Frontier area.

1961 Coating Conference Program Committee. Standing—J. T. Goodwin, R. I. Bashford, Jr., W. E. Welliver, Jr. (Publicity Chairman). Seated (Back Row)—L. A. Gilbertson, C. W. Cairns, H. R. Hall, R. W. Martinek (General Conference Chairman). C. G. Whelpton (Technical Program Chairman). Seated (Front Row)—A. W. Newbauer, E. R. Padavic, J. E. Chinn

Buffalo is well serviced by both air and rail transportation. For those planning to drive, Buffalo may be reached via the New York State Thruway.

Hotel reservations should be made at once and directly with the Statler-Hilton Hotel, Buffalo, N. Y. Please mention you are attending the TAPPI Coating Conference.

Maine-New Hampshire and New England Sections

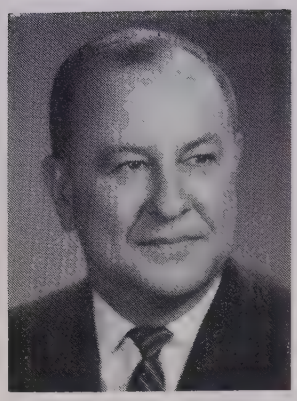
Final arrangements are being completed for a joint spring meeting of the Maine-New Hampshire and New England Sections of TAPPI at Wentworth-by-the-Sea in Portsmouth, N. H., June 9, 10, and 11, 1961.

The following committees have been appointed:

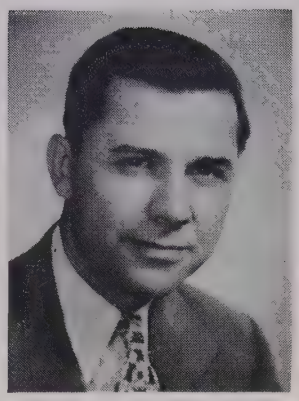
Budget—Alex E. Hutton, Jr., Fitchburg Paper Co.; Harold E. Pratt, Pejepscot Paper Co.

Local Arrangements—J. F. Wright, National Aniline Div., chairman; E. W. Strecker, Esleeck Mfg. Co.; Walter Wood, National Aniline Div.; Paul Shirley, Penick & Ford, Ltd.; Donald Thomson, Northeastern Sales; Cliffe Reppe, Hercules Powder Co.

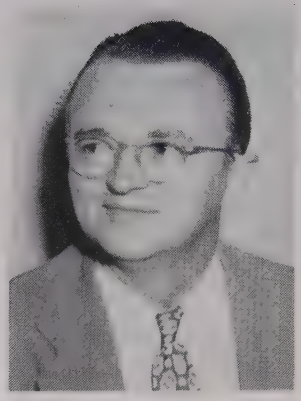
Ladies' Program—Wives of the officers.



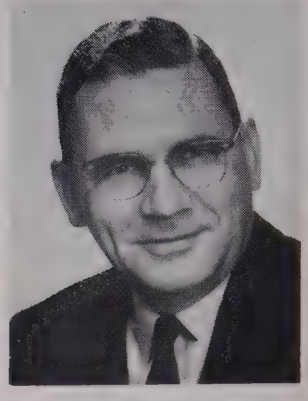
W. H. Aiken, Union Bag-Camp Paper Corp.



P. W. Bartholomew, Minnesota & Ontario Paper Co.



G. E. Kimble, Union Bag-Camp Paper Corp.



W. P. Lawrence, Champion Paper & Fibre Co.

Newly elected to the TAPPI Executive Committee

Technical Program—Joseph Theriault, Continental Can Co.; H. W. Osgood, S. D. Warren Co.; Malcolm White, Oxford Paper Co.; David Habib, Technifax Corp.
Publicity—John J. O'Brien, *Paper Mill News*, L. R. Adkins, Waterfalls Tissue Corp.

The subjects for the technical program will be bleaching and instrumentation.

Converting and Consuming Division

J. C. Pullman, American Cyanamid Co., New York, N. Y., general chairman of the TAPPI Converting and Consuming Division, has announced the formation of a Staff Advisory Committee within the division.

The purpose of this new group will be to give greater flexibility to the divisional activity by providing staff guidance to the various committees of the division. It was considered most desirable to take this step in view of the rapidly changing conditions in the converting and consuming industries resulting from the development of many new application techniques for the union of resins and other synthetic materials with papers.

The new advisory group is considering a change of scope and clarification of new objectives which will enable the division to render more effective service to the areas of the industry concerned with plastics, laminates, synthetic fibers, and other plastic-paper combinations.

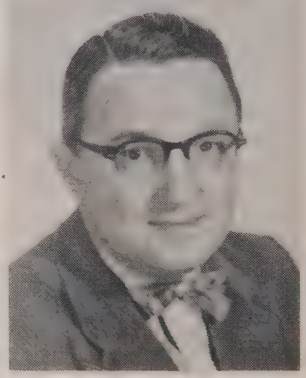
Members of the new advisory committee are: W. L. Hardy, International Minerals & Chemicals Co., Skokie, Ill.; T. A. Howells, The Institute of Paper Chemistry, Appleton, Wis.; B. W. Loheed, Chas. T. Main, Inc., Boston, Mass.; R. C. Sturken, Frank W. Egan Co., Somerville, N. J.

Staff Advisory Committee, Converting and Consuming Division. T. A. Howells, The Institute of Paper Chemistry; R. C. Sturken, Frank W. Egan Co.; J. C. Pullman, American Cyanamid Co.; R. W. Loheed, Chas. T. Main, Inc.; A. J. Winchester, TAPPI

1961 TAPPI Executive Committee

As reported by the Tellers Committee, Harold M. Annis, Oxford Paper Co., New York, N. Y., has been elected president of the Association to succeed James R. Lientz, Union Bag-Camp Paper Corp., Savannah, Ga.

John C. Wollwage, Kimberly-Clark Corp., Neenah, Wis., has been elected vice-president of the Association, replacing Harold M. Annis.



J. C. Wollwage, Kimberly-Clark Corp., vice-president, TAPPI

Joining them on the Executive Committee are four new men who have been elected to serve 3-yr. terms: W. H. Aiken, Union Bag-Camp Corp., New York, N. Y.; P. W. Bartholomew, Minnesota and Ontario Paper Co., International Falls, Minn.; G. C. Kimble, Union Bag-Camp Paper Corp., Savannah, Ga.; and W. P. Lawrence, Champion Paper and Fibre Co., Hamilton, Ohio.

The Executive Committee members whose terms have expired in February, 1961 are: P. S. Cade, Harding-Jones Paper Co., Middletown, Ohio; F. P. Doane, Jr., Bergstrom Paper Co., Neenah, Wis.; J. H. Heuer, Great Northern Paper Co., Bangor, Me.; and J. J. Koenig, Crown Zellerbach Corp., St. Louis, Mo.

British Symposium—The Formation and Structure of Paper

A second international meeting of high scientific caliber is being organized by the Technical Section of the British Paper & Board Maker's Association. The first was held in Cambridge in 1957 to survey "Fundamental Aspects of Fibers and Their Treatment for Papermaking" and a record of the papers and the discussions of them was published by the Technical Section with the title "Fundamentals of Papermaking Fibres."

It is the purpose of the second symposium to advance from this position by discussing "The Formation and Structure of Paper."

The conference will cover the five days, Sept. 25–29, 1961, and the sessions will be held at the Dyson Perrins Laboratory, Oxford, with Rhodes House opposite as registrants' club room. Registration for the conference will be on Sunday, September 24.

Several social events will be arranged for registrants and ladies who accompany them. At the moment, it is estimated

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that the symposium fee will be $12, the registrants' social fee will be $5 and the ladies' fee will be $7.

Information and a registration form can be obtained from the Technical Section office. A maximum of 250 applications can be accepted for the symposium and the applications will be dealt with therefore in strict rotation as received.

The record of papers presented at the symposium will be published afterwards uniformly with "Fundamentals of Papermaking Fibres."

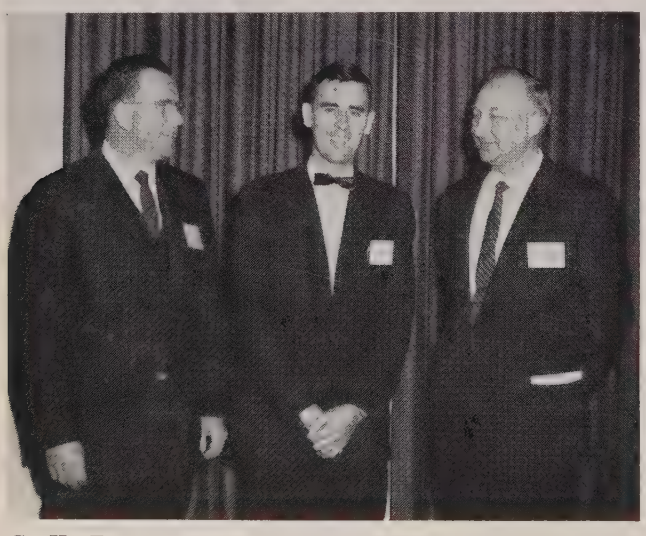
Accommodation for registrants and ladies accompanying them will be at Christ Church (one of the university colleges) or at the Randolph Hotel.

The address of the Technical Section office is St. Winifred's, Welcomes Road, Kenley, Surrey, England.

Third APPA-TAPPI Research Conference

The Third Annual Research Conference of pulp and paper industry was held on Nov. 4 and 5, 1960. Sponsored jointly by the American Paper and Pulp Association and the Technical Association of the Pulp and Paper Industry, the conference this year was at the Hotel Northampton, Northampton, Mass. Chairman of the conference was A. W. Plummer, assistant vice-president and director of research and development, Hudson Pulp and Paper Corp., South Windham, Me.

Forty-four technical representatives of the pulp and paper industry and 47 key scientists from colleges and universities gathered from all parts of the United States and Canada for



G. H. Tomlinson II, Howard Smith Paper Mills Ltd., Cornwall, Ont., lecturers; Peter Wrist, Mead Corp., Chillicothe, Ohio; J. H. Swanson, The Institute of Paper Chemistry, Appleton, Wis., at the Third APPA-TAPPI Research Conference

two days of intensive discussion of important fundamental research opportunities for future study. Research in paper formation, wood pulping, and chemical additives were a few of the many subjects covered.

Doctor E. R. Laughlin, secretary of the APPA Technical Committee, said this third annual conference again provided the opportunity for closer relations between paper technologists and key educators and scientists concerned with fundamental research.

In his keynote address during the opening session of the Conference, Dr. Ward Harrison, president of Allied Paper Corp., Kalamazoo, Mich., said, "Our industry offers unexcelled career opportunities for research oriented persons with good scientific training, as well as for technically trained people who are interested in the practical applications of the fruits of research as well as in research itself."

Mexican A.T.C.P.

The Associacion Mexicana de Tecnicos de las Industrias de la Celulosa y del Papel A.C. was officially constituted on Aug. 17, 1960, following a number of preliminary group and committee meetings, starting in June. At this meeting

Sandro Dante Cusi, Sergio Vadillo, Hans Lenz, Adalberto Tirado, Hector Hernandez, Jose R. Sana, A. M. Leth, Ricardo Millares, and Claudio Gonzalez

Adalberto Tirado A. of Fabricas de Papel Loreto y Pena Pobre S.A. was elected president. Ninety-five persons attended the first meeting which was devoted to organizational matters.

On September 30 a dinner meeting was held and attended by 125 persons. A film was shown depicting very old Mexican Indian original procedures for making paper and using the product for witchcraft, wizardry, and medical purposes.

A very successful technical meeting was held on October 28 at the Laboratories Nacionales de Fomento Industrial. Seventy-five members attended and inspected the facilities available for industrial research. One of these sections is devoted to cellulose, pulp, and paper research. The director of the Laboratories is Rafael Rojas Gutierrez.

Following the inspection tour two papers were presented. Salvador Carraseo, head of the pulp and paper section of the Laboratories, discussed the pulping properties of nonwoody plants such as bagasse, straw, bamboo, hemp, and other

At the Mexican A.T.C.P. meeting

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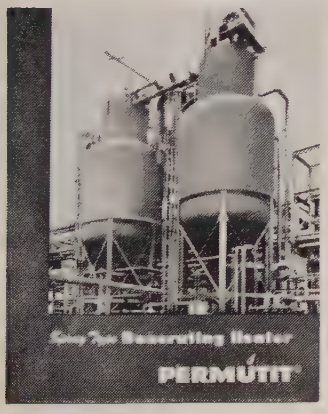

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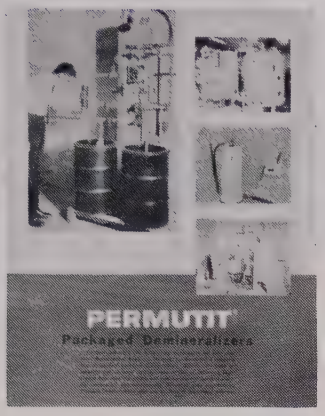

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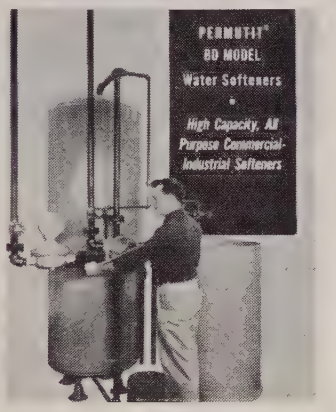

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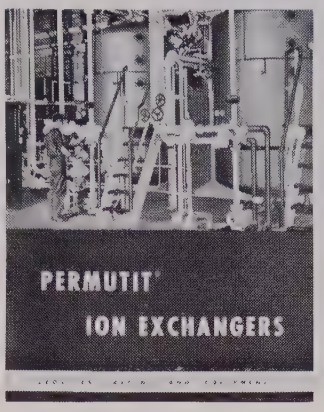
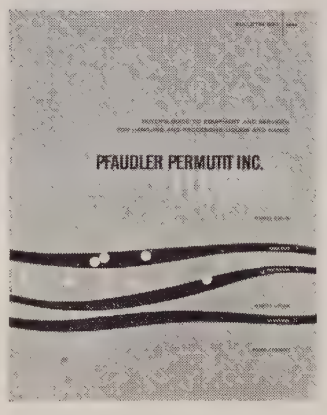


Ion exchangers: From Permutit—the only company to manufacture ion exchange resins and the equipment in which they are used—you can get a brief manual on use of ion exchange as a unit process for purification, recovery, addition, separation, concentration. **Bulletin 2508** covers Permutit resins and equipment.



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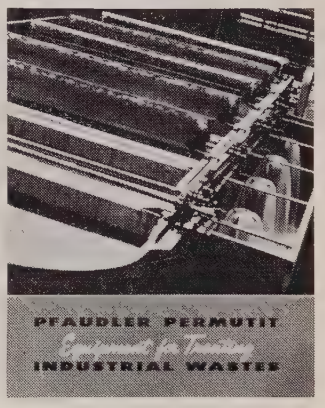
"New" metals for processing: Tantalum, titanium and zirconium are finding increased use, because of their exceptional corrosion resistance and strength. Corrosion, heat transfer and general application data on these metals, plus equipment available, are discussed in **Bulletin 978.**



Treating industrial wastes: Bulletin 4486 discusses types of industrial waste problems, equipment used, typical waste treatment systems.

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- ☐ 4486 Equipment for Treating Industrial Wastes
- ☐ 2357 Permutit Spray Deaerators
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Jose Antonio Hinojosa, Octavio Lara, Sandro Dante Cusi, and Sergio Vadillo

potential sources of pulp in Mexico. The second speaker, Pablo Aldrett of Kimberly-Clark de Mexico discussed the use of the vapor-purge system as applied to the cooking of bulky materials, other than wood. An extensive general discussion followed the presentation of the papers. The two papers will be published in the first number of the ATCP Magazine which will be issued soon.

On November 25 about 115 persons attended a special session at the Camara Nacional de las Industrias del Papel. Some amendments were made to the constitution to permit

Group attending the Mexican meeting

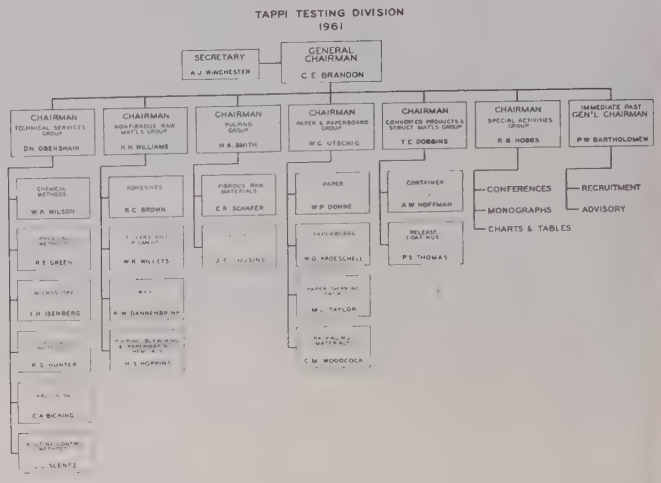
individuals who do not reside in Mexico to become members. (The initiation fee will be $8.00 and the annual dues $16.00.) Following the business meeting Lucas Tartorelli, forestry delegate of the United Nations (F.A.O.) in Mexico led a round-table discussion of the status and future of forests in both Mexico and other Latin American countries.

On December 16 a dinner dance was held in the Rondinella Room of the Alffer Hotel. About 200 people were present.

The annual meeting of the Association will be held in May 1961. Several papers are being prepared for this meeting. Anyone residing outside of Mexico is quite welcome to attend the meeting and to offer a paper for presentation. Communications should be addressed to A. M. Leth, Celulosa de Chihuahua S. A., Alabama 113, Mexico 18, D. F.

Eleventh Testing Conference

The Eleventh Testing Conference of the Technical Association of the Pulp and Paper Industry was held Sept. 27–29, 1960, at the Civic Auditorium; Grand Rapids, Mich. The conference is sponsored annually by the TAPPI Testing



Division. C. E. Brandon, Miami University, Oxford, Ohio, is general chairman of the division, and R. B. Hobbs, National Bureau of Standards, Washington, D. C.; is chairman of special activities.

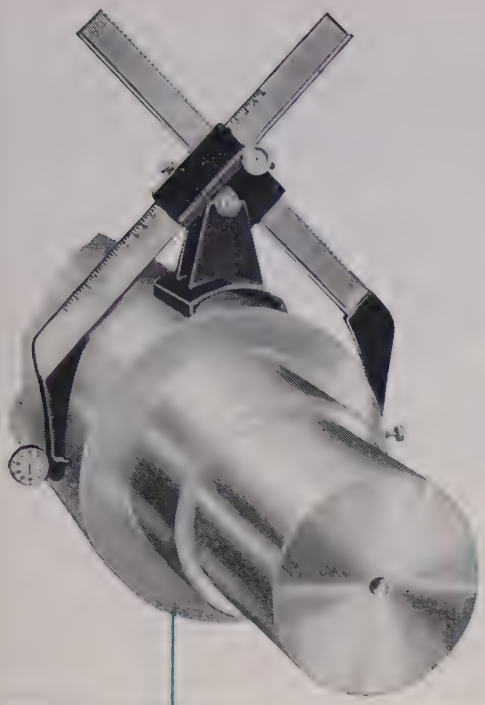
The conference was planned by the following committee:

W. H. Aiken, Personal Products Co., Milltown, N. J., *General Chairman.*
W. R. Willets, Titanium Pigment Corp., New York, N. Y., *Program Chairman.*
C. E. Jakeway, Packaging Corp. of America, Grand Rapids, Mich., *Local Arrangements Chairman.*
D. E. Byro, Michigan Carton Co., Battle Creek, Mich., *Hospitality and Registration.*
L. R. Beeman, Watervliet Paper Co., Watervliet, Mich., *Hospitality and Registration.*
C. Russell, Allied Paper Corp., Kalamazoo, Mich., *Hospitality and Registration.*
F. Yankoviak, KVP-Sutherland Paper Co., Kalamazoo, Mich., *Hospitality and Registration.*
G. P. Ritzema, KVP-Sutherland Paper Co., Parchment, Mich., *Mill Visits & Transportation.*
R. Tubergen, Corn Products Sales Co., Grand Rapids, Mich., *Hotel Arrangements.*
J. B. Jasmin, Elliott Co., Grand Rapids, Mich., *Hotel Arrangements.*
W. R. Bachelder, Testing Machines, Inc., Mineola, L. I., N. Y., *Exhibits.*
R. Glaser, MacSim Bar Paper Co., Otsego, Mich., *Exhibits.*

In the following account, brief abstracts of the paper are given. The full text of all the papers presented will appear in various issues of *Tappi.*

On Tuesday morning, September 27, the conference was opened by General Chairman W. H. Aiken. Mr. Aiken introduced the Hon. S. J. Davies, Mayor of Grand Rapids, who welcomed the delegates to the city. C. E. Brandon, general chairman of the Testing Division, then opened a short session during which each of the group chairman described the activities of the committees in his group. Committee activity is open to all TAPPI members, and it was pointed out that all conferences were welcome

C. E. Brandon, Miami University; chairman, Testing Division



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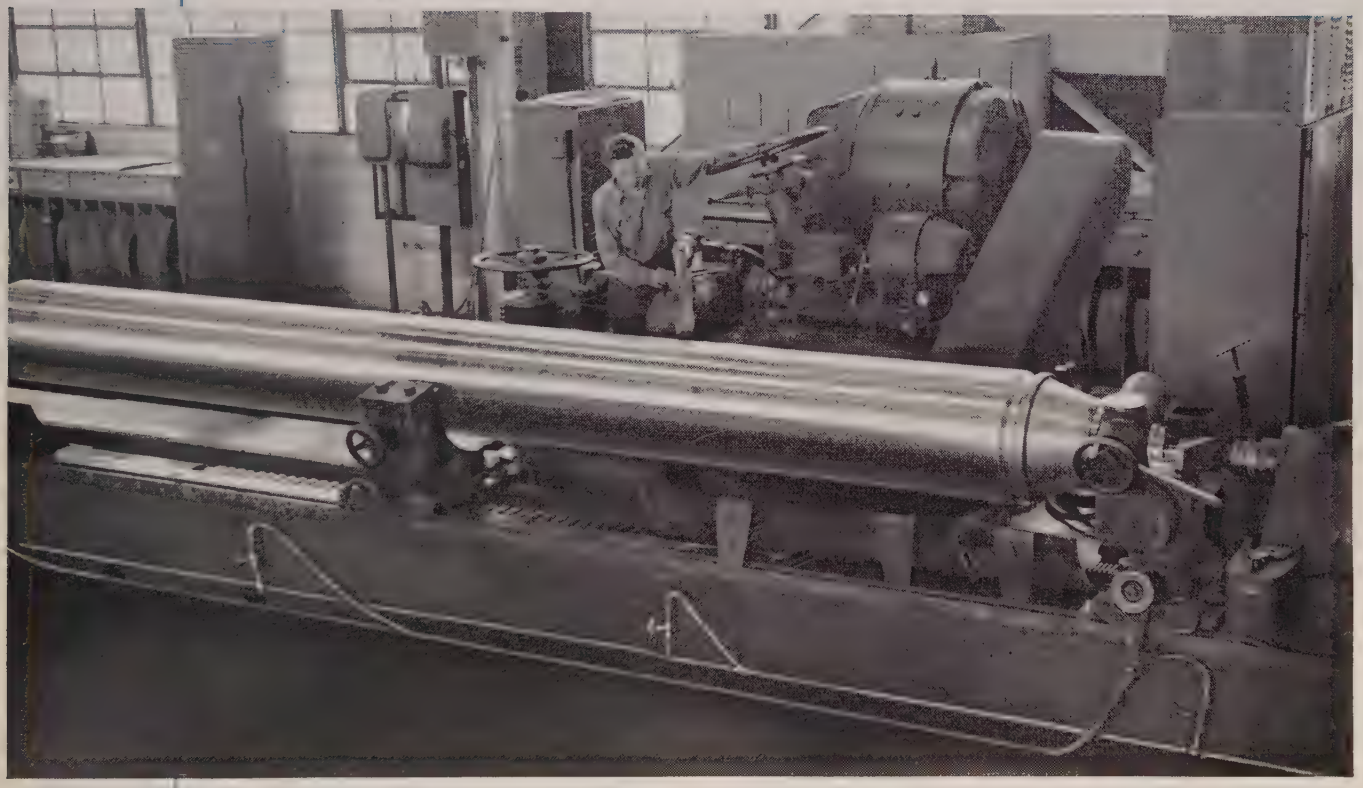

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Testing Division Steering Committee—seated: D. N. Obenshain, West Va. Pulp & Paper Co., chairman, Technical Services Group; R. B. Hobbs, Nat'l Bureau of Standards, chairman, Special Activities Group; T. E. Dobbins, American Can Co., chairman, Converted Products Group; K. H. Williams, Mid-States Gummed Paper Co., chairman, Nonfibrous Raw Materials Group; P. W. Bartholomew, Minnesota & Ontario Paper Co., immediate past chairman, Testing Division; H. A. Smith, The Mead Corp., chairman, Pulping Group; M. A. Burnston, TAPPI; Standing: A. J. Winchester, TAPPI, secretary, Testing Division; C. E. Brandon, Miami University, Oxford, Ohio, general chairman, Testing Division

to attend the meetings of their choice in order to acquaint themselves with the committee work. The accompanying chart shows the organization of the Testing Division and the names of the group and committee chairmen. The rest of the morning and all afternoon on September 27 were devoted to meetings of the Testing Division Committees. These are working meetings during which the committees plan the revision of existing TAPPI methods and the preparation of new ones.

Relative Humidity Symposium

On Wednesday Sept. 28, 1960, a symposium on Relative Humidity and Paper Test Methods was held under the joint sponsorship of TAPPI and the American Society for Testing Materials, Committee D-6, Paper and Paper Products. The program for this all-day session was planned by T. W. Lashof, National Bureau of Standards, Washington, D. C.

H. A. Birdsall, chairman of ASTM Committee D-6, was moderator of the morning session, during which the following papers were presented.

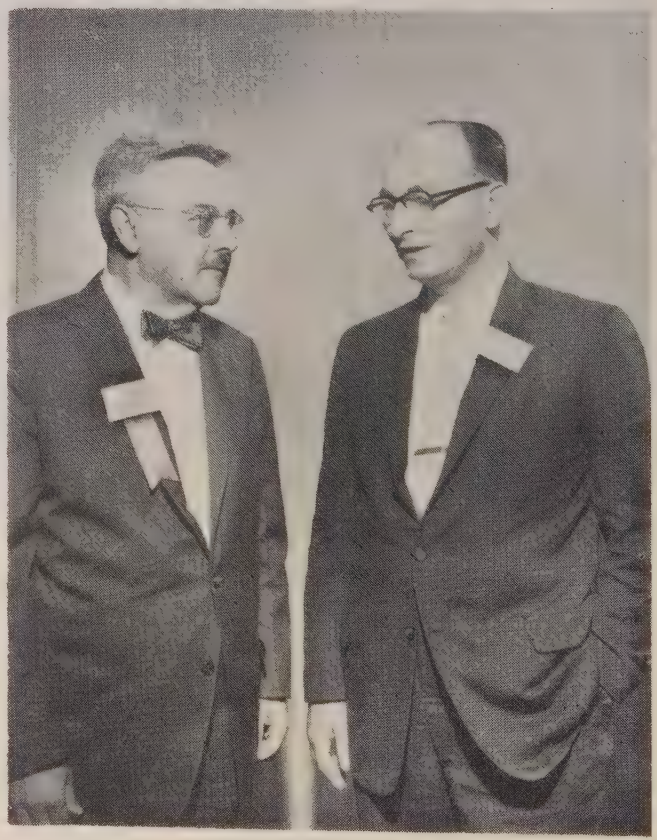
"Reasons for 65% R.H. and 20°C.," by W. H. Brecht, Institut fur Papierfabrikation, Technische Hochschule, Darmstadt, Germany. In America, the standard conditions for paper testing rooms are 50 ± 2% R.H. and 23 ± 2°C. European countries have used for many years other standard conditions which are 65% R.H. and 20°C. with small variations in tolerance limits. In Germany, for instance, the tolerance limits are ±2% R.H. and ±1°C. The paper describes how these standard conditions came about and discusses their advantages and disadvantages.

"The Effect of Relative Humidity of the Stress-Strain Properties of Multiwall Paper," by G. A. Bernier and W. E. Carlson, St. Regis Paper Co., Carthage, N. Y. In usage, multiwall bag materials are subjected to loading conditions which are not necessarily of rupture proportions. In addition to this, they are subjected to a wide range of humidity, temperature, and time conditions. In the past, traditional tests have been tensile, stretch, and tearing resistance. With the advent of the new extensible papers, such tests as tensile-energy-absorption, Frag bursting energy, and impulse testing have appeared. While these test methods serve a useful control or screening function, they yield little basic information as to the mechanism or history of failure in multiwall materials. Therefore, it is desirable to develop an acceptable test method which will explain the effects of time, temperature, humidity and previous history on the field performance of all types of multiwall materials.

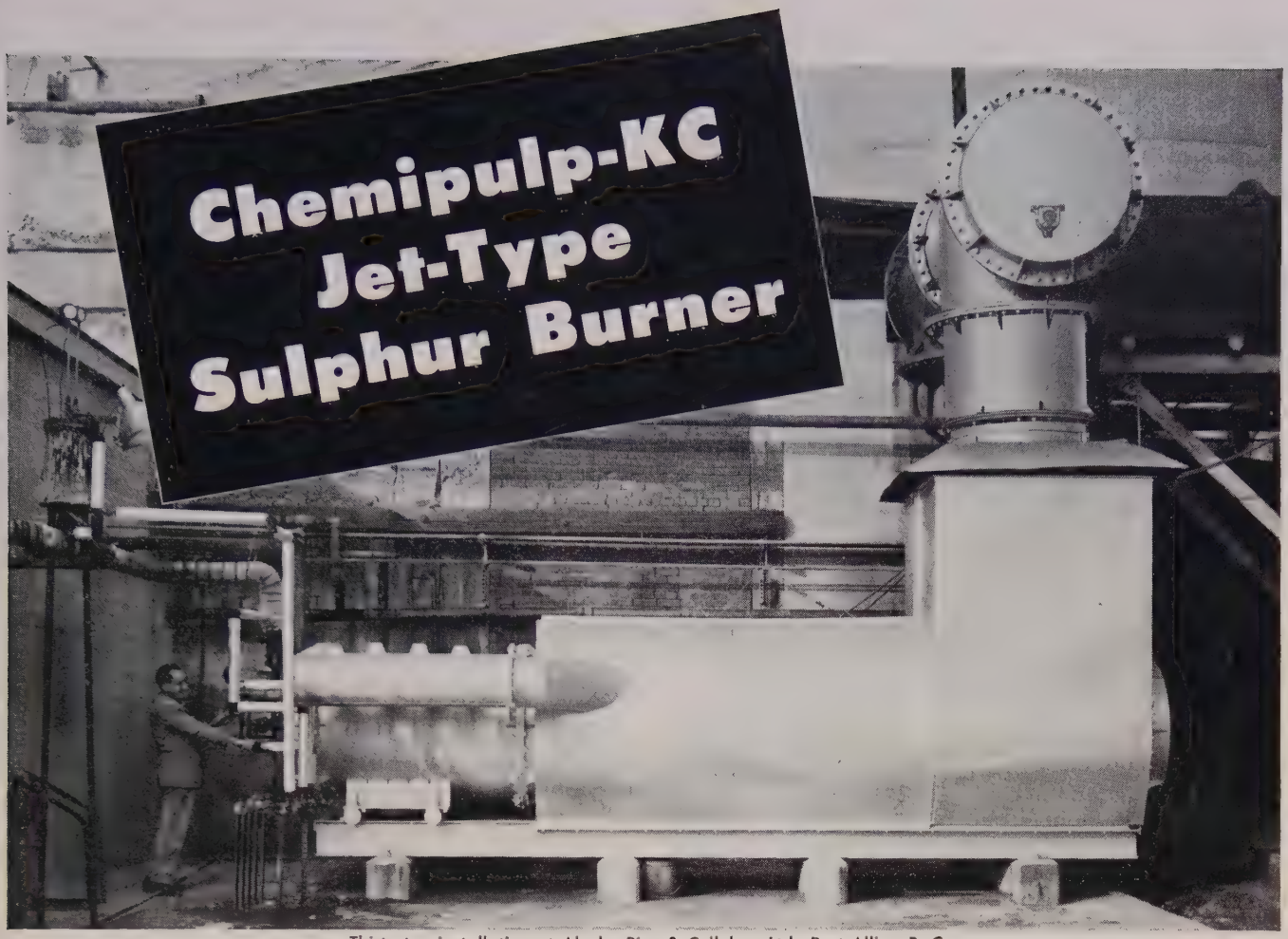
The current study was undertaken to determine humidity's effect on some of the stress-strain properties of a wide range of types of multiwall bag materials including the conventional flat kraft, compressively shrunk extensible paper, creped and embossed extensible paper, microcrepe, and a viscose fiber web bonded with a hydrophobic binder. As was expected, tensile strength decreased with increasing humidity, while stretch and tearing resistance increased. Recovery properties of the materials tested exhibited gross differences, indicating that the method of manufacturing exerts an appreciable influence on the stress-strain properties of the materials. Recovery properties of the kraft materials tested decreased with increasing humidity while those of the viscose fiber web bonded with the hydrophobic binder increased, indicating that failure at high humidities is primarily due to bond failure. The apparent modulues of elasticity, which is related to the rigidity of the material, decreased with increased humidity. The flat kraft material was much more stiff than the extensible papers.

A possible mechanism of failure has been suggested by the effect of humidity changes on recovery and rigidity characteristics in corroboration with field performance of multiwall sacks and the stress-strain characteristics of these materials at high rates of elongation.

"Hygroexpansivity of Tabulating Card Stock," by T. D. Callinan, J. S. Crimi, P. M. Schwartz and L. H. Wirtz, International Business Machines Corp., Yorktown Heights, N. Y. The hygroexpansivity of five tabulating card stocks have



W. R. Willets, Titanium Pigment Corp., program chairman, and T. W. Lashof, National Bureau of Standards, Washington, D. C., chairman, relative humidity program



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Relative Humidity Symposium—morning session: T. W. Lashof, National Bureau of Standards, Chairman; H. A. Birdsall, chairman, ASTM Committee D-6, Bell Telephone Laboratories, moderator; F. C. Globig, Champion Paper & Fibre Co.; J. d'A. Clark, chairman, TAPPI Standards Committee, Oregon State College. Standing—l. to r: W. E. Carlson, St. Regis Paper Co.; T. D. Callinan, International Business Machines Corp.; W. A. Wink, The Institute of Paper Chemistry

been determined over the relative humidity range 0–98%. A Thwing-Albert NBS Expansiometer was employed in the tests. Unbleached sulfate, semibleached sulfate, and semibleached sulfite stocks were studied. Their chemistry, fiber distribution, and moisture adsorption isotherms were determined. The effect of humidity cycling on the hydroexpansivity coefficients were established. The anomalous decrease in dimensions which occurs at elevated humidities has been studied. The hygroexpansivity coefficient has been found to depend in part on the magnitude and relaxation times of strains which develop in the card stock during manufacture.

"The Effect of Relative Humidity on Paper Properties," by W. A. Wink, The Institute of Paper Chemistry, Appleton, Wis. Many of the physical properties of paper are strongly influenced by relative humidity and by the moisture content history of the paper. Data on various physical properties are presented. These show (a) the manner in which the physical properties change with relative humidity, (b) the hysteresis and humidity cycling effects on measurements made at 50% R.H., and (c) the stress relaxation effects resulting from exposure of paper to high relative humidities. The relative importance of the foregoing are discussed with respect to the present TAPPI tolerances on the conditioning and testing of papers.

Following the presentation of the above four papers, a discussion based on the papers was led by James d'A. Clark, chairman, TAPPI Standards Committee, Oregon State College, Corvallis, Ore.

D. N. Obenshain, West Virginia Pulp and Paper Co., Luke, Md., was moderator of the afternoon session, when the following papers were presented.

"Some Developments in the Measurement of Relative Humidity," by A. C. Poulter, Albert E. Reed and Co., Ltd., Maidstone, Kent England. Description and review of some of the more recent techniques, particularly in this country, which have been developed for measuring relative humidity under the various conditions related to the scope of the paper field.

"Humidity Standards," by A. Wexler, National Bureau of Standards, Washington, D. C. This paper describes and discusses instruments which may serve as primary and secondary humidity standards, including a gravimetric hygrometer, now under development at the National Bureau of Standards, to a basic reference for humidity measurements. It reviews the art of testing and calibrating hygrometers. The use of precision humidity generators for producing atmospheres of known humidity is outlined. Methods and techniques of obtaining fixed humidity points are given.

"The Design and Control of Test Rooms and Small Ovens," by J. A. Cairns, The Printing, Packaging and Allied Trades Research Assoc., Leatherhead, Surrey, England. The general design of humidity cabinets of both the saturated salt solution and the injection types is discussed, indicating the more important features of the mechanical construction, together with hints on the operation and maintenance of such cabinets.

Some methods are given for measuring the conditions inside such enclosures, as well as the requirements for the close control of these conditions.

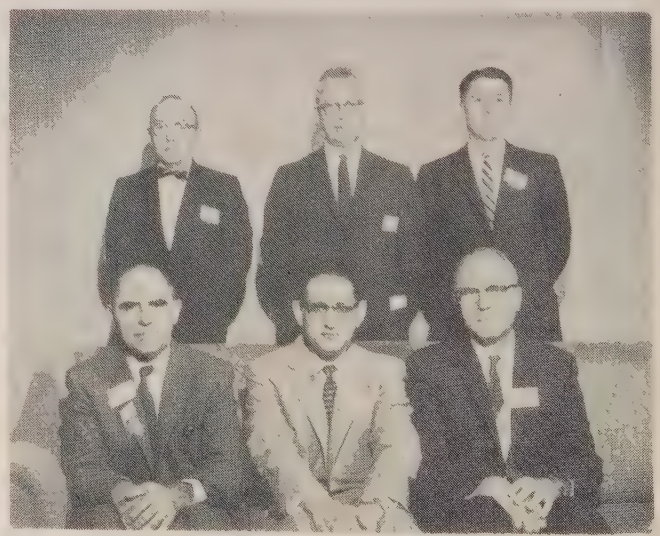
The paper also deals with the design of small testing or storage rooms (of about 1000 cu. ft. capacity), these rooms representing the intermediate stage between a humidity cabinet and a conditioned laboratory.

The problems encountered in rooms of conventional construction are outlined and a description is given of a novel building method which will apparently overcome some of these problems. A suitable plant for conditioning such a room is described.

A brief description is given of the various methods of air conditioning a full sized laboratory and the suitability of certain control systems is discussed.

"A Room for Mill Control Testing of Paper," by L. L. Clapp, St. Regis Paper Co., Pensacola, Fla. A room located near paper machines and designed to accommodate considerable traffic while maintaining atmospheric conditions moderately close to standard has been in successful operation for six years. A system for rapidly conditioning paper samples for testing has been used therein for three years. A description is presented of the room, the air conditioning equipment, the control instrumentation, and the rapid conditioning unit. The influence of the practice of rapid conditioning on the sampling, testing, and reporting sequence is discussed.

"The Constant Temperature Room as a Testing Facility," by F. M. Gavan, Chairman, ASTM Committee E-1, Sub 14, "Conditioning and Weathering," Armstrong Cork Co.,



Relative Humidity Symposium—afternoon session: D. N. Obenshain, West Va. Pulp & Paper Co., moderator; A. Wexler, National Bureau of Standards; W. A. Wink, Institute of Paper Chemistry. Standing—l. to r: L. L. Clapp, St. Regis Paper Co.; F. M. Gavan, chairman, ASTM Committee E-1, Sub 14 "Conditioning and Weathering," Armstrong Cork Co.; R. B. Hobbs, National Bureau of Standards

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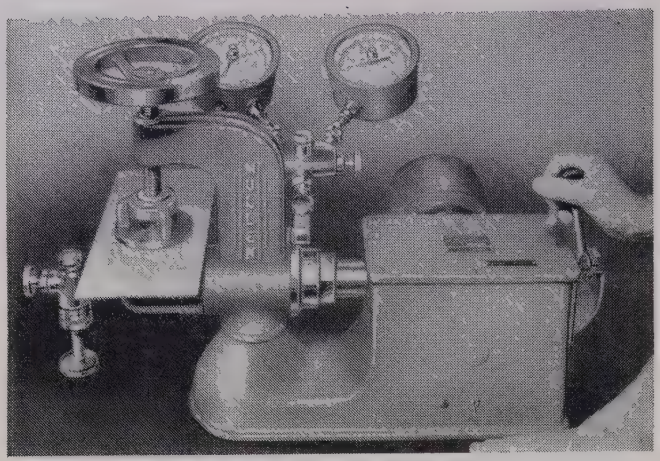

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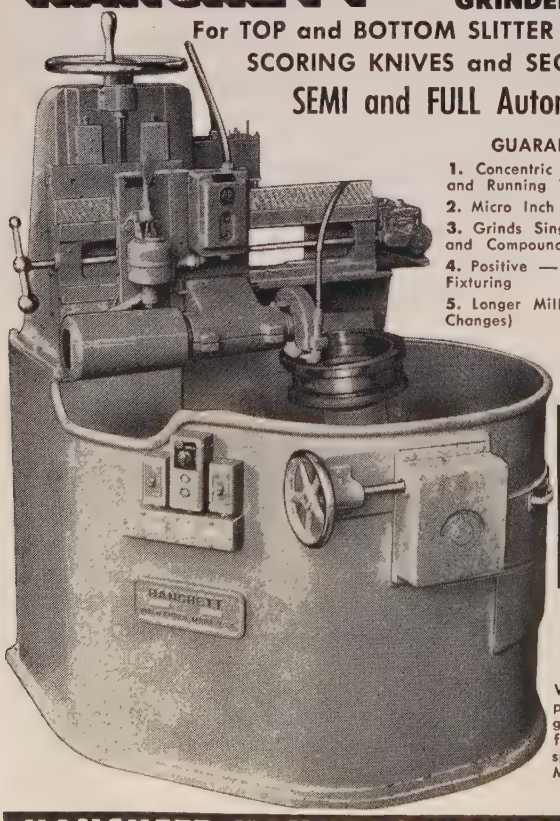

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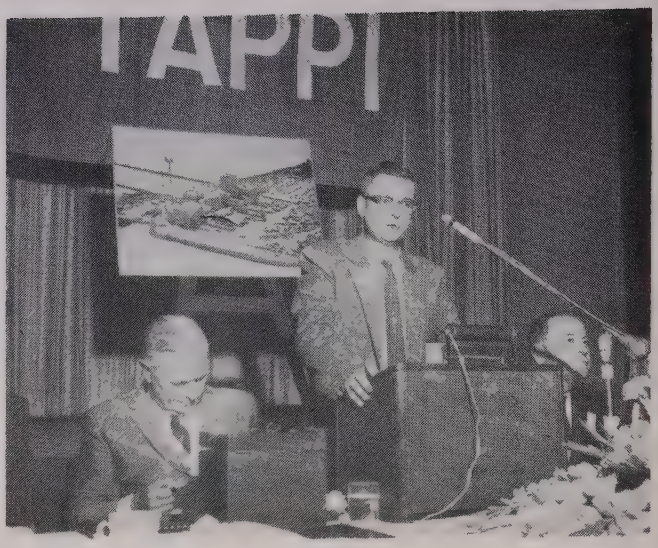


W. E. Kite, Simpson-Lee Paper Co., chairman, Kalamazoo Valley Section, TAPPI

Lancaster, Pa. In planning the new Research and Development Center the Armstrong Cork Co. was influenced in the design of the constant temperature rooms by its long experience with hygroscopic and thermal sensitive materials. The decision was made to provide five interconnecting test rooms for the Physical Test Department involving 40 by 80-ft. total space controlled to 70 ± 1°F. and 50 ± 2% R.H. These conditions were to be maintained under all normal loads and with high outside loads. (It was felt that if these standards of precision were met the projected change to 73.5°F. to satisfy E 41 would result in an easily obtainable standard of high precision.) Associated with these rooms are one 20 by 20-ft. research constant temperature room and one 10 by 10-ft. low relative humidity spectrographic room used by the Analytical Department. In addition there is a sixth room in the Physical Test Department used for asphalt tile testing and thermal conductivity work and controlled at 77° ± 10°F. and 50 ± 2% R.H. All of these eight rooms are conditioned by three 30-hp. York compressors and the humidity is controlled and recorded by Foxboro dew cells.

The discussion includes design considerations, methods of air distribution, the precision desired and the loads provided

W. H. Aiken, Union Bag-Camp Paper Corp., formerly with Personal Products Corp., general chairman, Eleventh Testing Conference

for, the performance obtained, the maintenance standards and methods, and practical recommendations. Mention is made of a separate sample preparation room where samples are cut and stored in constant temperature conditions while awaiting tests. Illustrations are provided of facilities, instruments, and performance charts.

Discussion on the above papers was led by R. B. Hobbs, National Bureau of Standards, Washington, D. C.

Annual Banquet

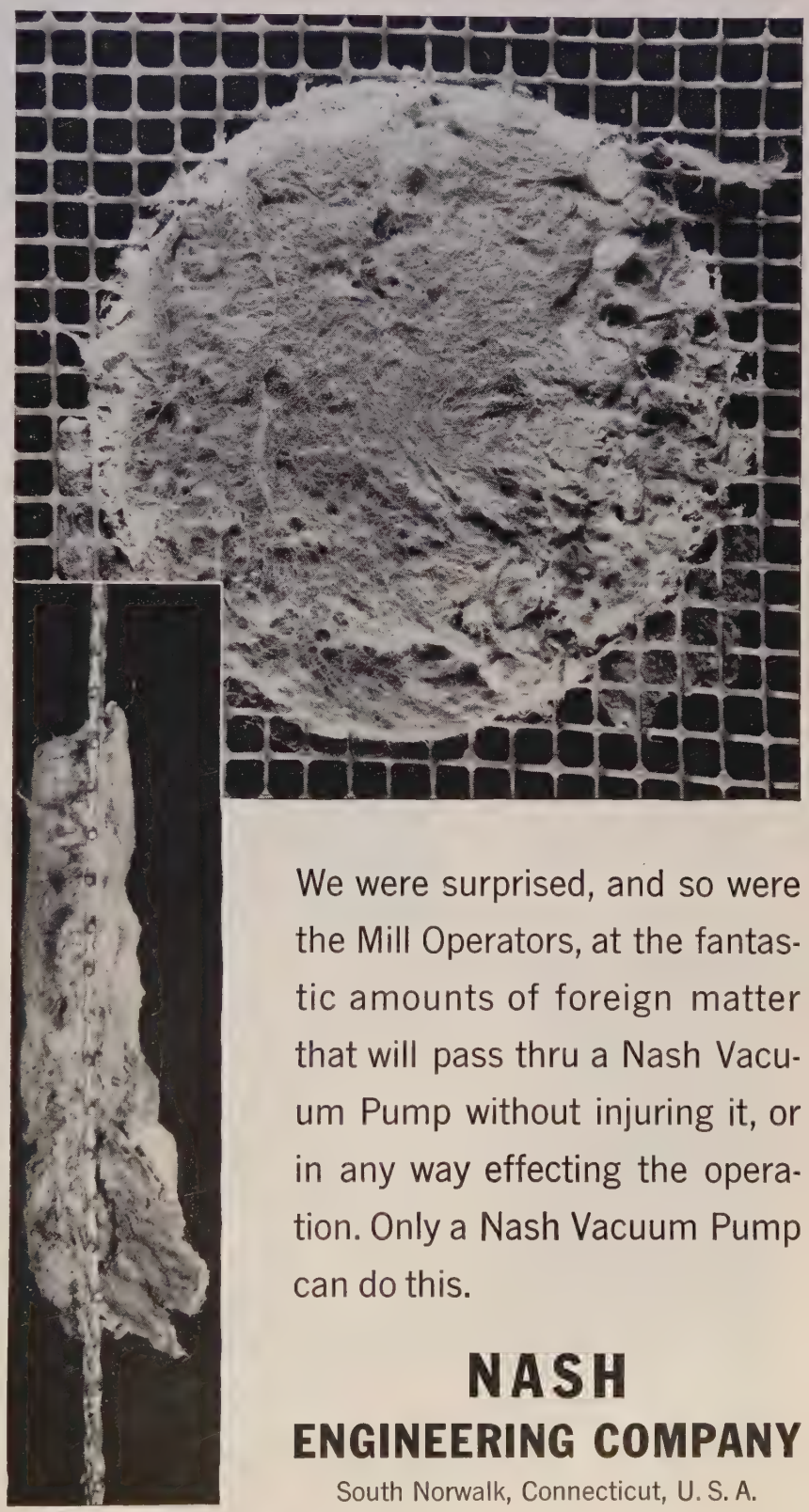
On Wednesday evening, Sept. 28, 1960, the annual banquet of the Testing Division was held, with W. H. Aiken general conference chairman, acting as toastmaster. The banquet was jointly sponsored by the Kalamazoo Valley Section of TAPPI and the Eleventh Testing Conference. W. Kite, Simpson-Lee Paper Co., Vicksburg, Mich., is chairman of the local section. Mr. Aiken introduced the head table guests and members of the conference committee, and called on P. E. Nethercut, who presented Certificates of Appreciation on behalf of the Association to Mr. Aiken, the retiring chairman of Paper and Paperboard Group, Testing Division, and to J. R. Gunning, retiring chairman of the TAPPI Routine Control Methods Committee. Chairman Aiken then called upon Mr. Kite, who introduced the guest speaker, W. L. Cisler, Detroit Edison Co., Detroit, Mich. The text of Mr. Cisler's address, on atomic power development, appeared in the October, 1960, issue of *Tappi*.

Water Symposium

On Thursday morning, September 29, a water symposium was held under the sponsorship of the TAPPI Water Committee. This session was moderated by E. S. Petrich, Howard Paper Mills, Urbana, Ohio, and had as its theme "Water, the Most Important Nonfibrous Raw Material." An introductory address on this subject was given by R. W. Purdy, Michigan Water Resources Commission, Lansing, Mich., after which the following papers were presented.

"Process Water," by R. K. Bamman, Champion Paper and Fibre Co., Hamilton, Ohio. Process water testing starts before the mill construction plans are prepared and continues until the final pound of paper has been processed. Different processes and different products may be produced with different quality waters but all of the water used must be tested to insure that its quality does not fall below the minimum established to permit quality production at highest capacity.

We put a screen on the intake of a Nash Paper Mill Vacuum Pump for a few hours . . .



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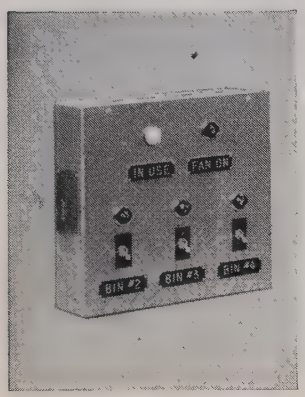

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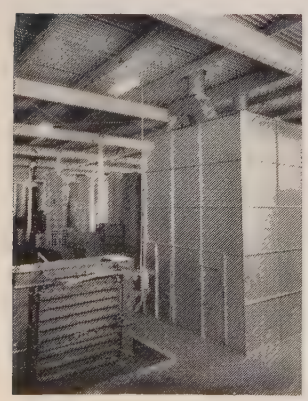

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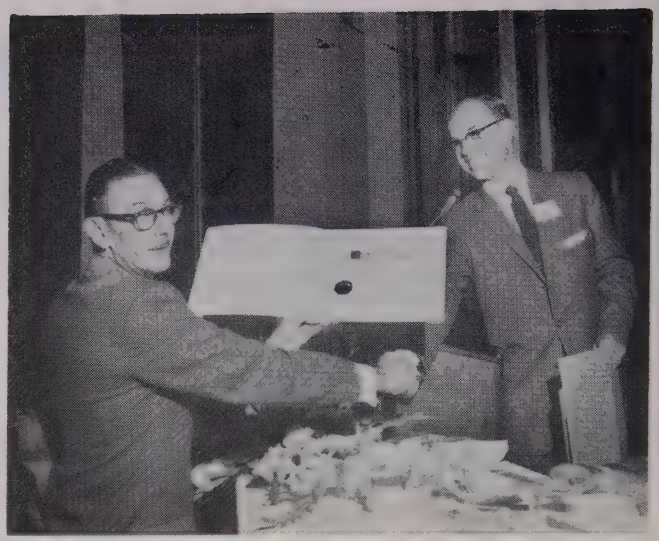


P. E. Nethercut, TAPPI, presenting Certificate of Appreciation to J. R. Gunning, supervisor Fine Paper Section, Abitibi Power & Paper Co. Ltd., Central Research Div., Provincial Paper Sect., Georgetown, Ont.; retiring chairman of Routine Control Methods Committee

Routine testing of the mill water supply may be limited to hourly determination of turbidity, temperature, hydrogen ion concentration (pH), and chlorine residual. Any sudden change in the results of any of these tests should be investigated by a more thorough examination to pin-point the reason and to determine what corrective action, if any, must be undertaken to insure continued quality production at the normal operating capacity.

Higher quality papers require higher quality water which demands additional testing. Although some special tests are beyond the scope of this paper, further tests were described for general mill application.

The final sale of tons of paper may depend upon the results of the tests performed on a few ounces of water. The competitive nature of the paper industry demands the use of quality raw materials including quality tested water.

"Waste Water," by W. A. Flower, Howard Paper Mills, Inc., Urbana, Ohio. The purposes of testing paper mill water are to determine the amount of materials lost, and the pollution load being discharged to the receiving stream. No attempt will be made here to discuss the standard analyses. Rather, some of the mechanics of waste-water testing were presented, along with some of the author's own experiences in this field.

P. E. Nethercut, presenting Certificate of Appreciation to W. H. Aiken, retiring chairman of Paper & Paperboard Group

Banquet: P. W. Bartholomew, Minnesota & Ontario Paper Co.; C. E. Jakeway, American Box Board Co.; W. R. Willets Titanium Pigment Corp., program chairman; J. d'A. Clark, Oregon State College; C. E. Brandon, Miami University, general chairman, Testing Division; W. L. Cisler, Detroit Edison Co., speaker

The essential part of any white water analysis are flow measurement, sampling, analysis, and expression of results. Conditions and requirements may vary with different mills of geographic areas, however, all will have these basic steps.

The type of test performed depends on products manufactured, and the requirement of the local water pollution control authority. For cost analysis it is usually necessary to test for suspended solids (fiber and filler) and certain dissolved solids. Regulatory agencies may want to know the temperature, B.O.D., pH, and a settleable solids.

Unusual circumstances occasionally require methods which have been especially adapted to apply to a special situation, such as the presence of fillers in a state of colloidal dispersion, or partially dissolved solids.

The accuracy required in white water testing is usually less than other chemical analyses. As a result, procedures can, and usually are, kept as simple as possible. Accuracy must be sufficient, however, to satisfy requirements of both cost accounting and regulatory agencies. Each mill must determine the practices best suited to its needs.

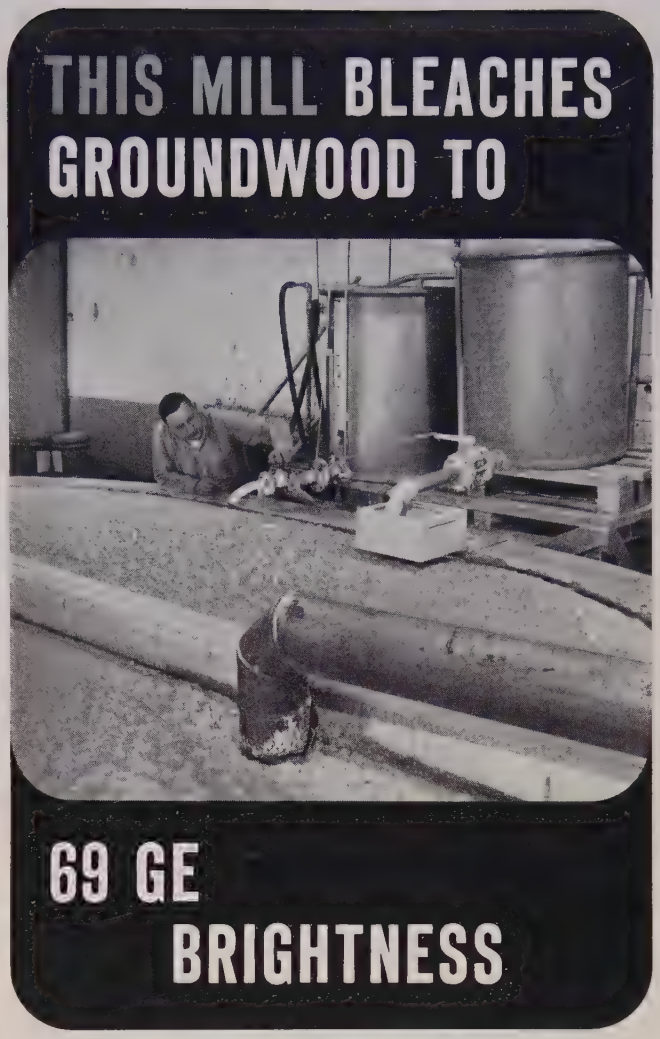
"Paper Mill Boiler Feed Water Practices," by M. H. Borland, The Mead Corp., Chillicothe, Ohio. Quantitatively, the water used in the steam generating cycle of a modern paper mill is a small part of the total amount used. For reliable, continuous operation of the mill it is essential that the returned condensate and make up water be properly treated. This treatment will allow boilers to operate the full year between inspections without excessive scale or other conditions forcing unscheduled outages. This treatment will allow turbines to operate several years without problems in the area of the steam path. This treatment will also minimize scaling and pitting of steam heating equipment and condensate return lines.

The higher temperatures and pressure of modern boilers accelerate chemical reactions. This requires that more care be given to the treatment used and that it be held within closer limits.

This paper describes the steam generating system of a large paper mill and the different types of feedwater treating methods at various pressures and temperatures.

Final Session

The last technical session of the Eleventh Testing Conference was held on Thursday afternoon, Sept. 29, 1960, under the chairmanship of J. R. Gunning, Abitibi Power &



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Banquet: W. H. Aiken, Personal Products Corp.; A. H. Nadelman, Kalamazoo, Mich.; W. L. Kite, Lee Paper Co.; P. E. Nethercut, TAPPI; W. F. Bachelder, Testing Machines, Inc.; J. D. Chadderdon, The KVP Co.; R. B. Hobbs, National Bureau of Standards

Paper Co., Sault Ste. Marie, Ont. The following papers were presented.

"Factors Influencing Testing of Gummed Tape," by E. Werle, Darling and Co., Chicago, Ill. As the title implies, the talk deals with the factors involved in the testing of rewettable gummed paper tape. Since precise methods are not available for the determination of the important property of tape in regard to how well it performs, consideration was given to such artful factors as are involved in performing the tests and interpreting the results.

"Some Variables Affecting the Viscosity and Adhesive Strength of Pigmented Paper Coating," by L. E. Georgevits and W. L. Marino, The Borden Co., Bainbridge, N. Y. Subcommittee IV—Section A of A.S.T.M. Committee D-25 has been studying test methods for casein and isolated soy protein as related to their use in paper coating. Two of the most important of these properties are viscosity and adhesive strength. In cooperative work, poor correlation has been obtained between laboratories. This study reviewed the effect of temperature, per cent solids, adhesive ratio, pH, alkali, coat weight, paper, drying conditions, mixing conditions and pigment on viscosity and adhesive strength. Viscosity values were obtained in most cases using a Brookfield viscometer, but other instruments were also tested. Adhesive strength was determined using both the Dennison wax pick test and the I.G.T. printability tester.

"Survey of Sampling and Precision Requirements in Present TAPPI Test Methods," by C. A. Bicking, The Carborundum Co., Niagara Falls, N. Y. The TAPPI standard methods for testing of pulp and of paper were surveyed to determine what they specify as to sampling, selection of test specimens, and testing precision. A detailed analysis was made of size and nature of samples, of dimensions and number of test specimens, and of statements regarding precision and accuracy. In most of the methods the requirements for sampling and test method preparation can be clarified and made more specific. There is no information on expected precision in most of the methods. In no instance is information given on probability levels associated with statements made about precision. The most common information found in the minority of methods which mentions anything related to precision is the expected agreement of duplicate tests. The activities of the Precision Committee are directed toward verifying existing precision statements as well as obtaining information which will lead to valid statements in all of the methods.

Banquet: P. E. Nethercut, TAPPI; W. F. Bachelder, Testing Machines, Inc., secretary, Paper Testing Committee; J. D. Chadderdon, The KVP Co.; R. B. Hobbs, National Bureau of Standards; A. H. Hupp, Watervliet Paper Co.; D. N. Obenshain, West Va. Pulp & Paper Co., chairman, Technical Services Group; A. J. Winchester, TAPPI

"Measurement of Fiber Flexibility," by A. A. Robertson, E. Meindersma, and S. G. Mason, Pulp and Paper Research Institute of Canada, Montreal, Que. A simple apparatus and method for the estimation of fiber flexibility was described. The method is based on the observation that a fiber, suspended in a liquid and subjected to laminar shear, describes a rotational orbit which reflects the flexibility of the fiber. Observation of the behavior of a representative sample of fibers under standard conditions permits the evaluation of a flexibility index for the pulp. Both wet and dry flexibility may be determined by this method.

A standard procedure for useof the apparatus was outlined and sources of error are discussed. Limitations and extensions of the method are pointed out and the application to pulping and papermaking studies is suggested.

Experiments were described which relate to the principles of the method, the choice of standard conditions and procedure, and the significance of the measurement.

"Calibration of the IGT Printability Tester," by D. S. Dixler, Air Reduction Co., Murray Hill, N. J. A simple electrical circuit has been designed and constructed which can readily be coupled to the printing device of the I.G.T; printability tester. This circuit permits the measurement of the instantaneous velocity of the printing sector at each instant of its travel (thus the printing speed at each distance along the printed test strip). It has been found that the "standard" curve provided by the manufacturer did not accurately describe either of two I.G.T. printability testers which were calibrated by means of our electrical device; nor did the two printability testers agree with each other.

"Development of Dirt Contribution Factors for Dirt in Pulpwood Chips," presented by B. E. Lauer, H. B. Santos, T. C. Rowland, and E. C. Birkhimer, University of Colorado, Boulder, Col. A study has been conducted to identify all the varieties of dirt in samples of pulpwood chips and to determine the relative contribution of each type to the dirt specks in the pulps prepared from them. The study was initiated on a sample of Englemann spruce cooked by the sulfite process.

The steps involved in the work were as follows: (1) the identification and the separation of dirt types into each possible basic separable class, (2) the preparation of pulp from each class of dirty chips, and (3) the estimation of the dirt content of the resultant pulps.

There were 15 basic dirt types identified. Each of the types of dirt which were studied in detail made some posi-

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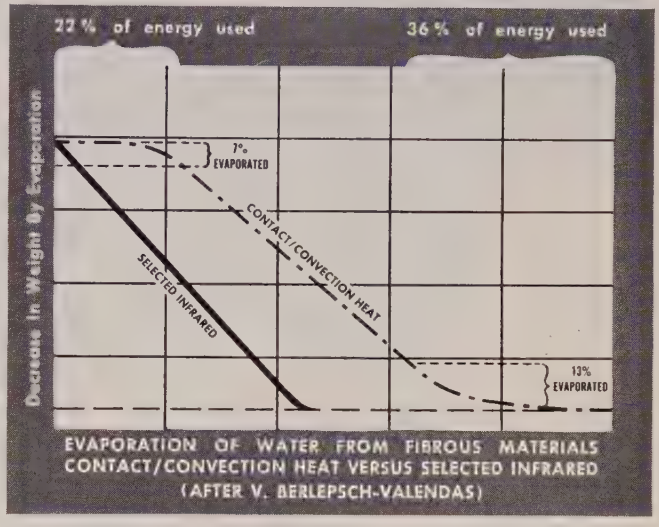

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tive contribution of dirt in the pulps which were produced.

This study was financed in part by TAPPI Research Grant No. 43 and sponsored by the Fibrous Raw Materials Testing Committee.

"Identification of Coniferous Woods," presented by B. F. Kukachka, Forest Products Laboratory, Madison, Wis. The identification of coniferous woods is generally regarded as being more difficult than for the hardwood species. This is due to that fact that conifers are more elemental in their structure and, as a consequence, the number of diagnostic features that may be employed is proportionately smaller. The generic identity of a given conifer can be determined without undue difficulty; however, specific identity can be accomplished only if the group is relatively small, the species with the group are well defined anatomically, or the species has a well-defined range that does not overlap that of a related species.

Instructions are given here in the sequential use of primary diagnostic features in the identification of coniferous woods. These may be used from the data chart or by sorting marginally perforated cards. Microscopic features are necessarily emphasized because of the greater accuracy obtainable through their usage. The majority of the species described are found in the continental United States and Canada; however, several exotic species found in commercial channels are also included.

This study was financed in part by TAPPI Research Grant No. 43 and sponsored by the Fibrous Raw Materials Testing Committee.

"The IBM Carbon Paper Intensity Tester," Presented by R. S. Drown, International Business Machines Corp., Endicott, N. Y. The construction of and the procedure for operating a device known as the IBM carbon paper intensity tester was discussed.

The instrument consists of two accurately machined, hardened and chrome plate steel rollers driven at a speed of 50 ± 2 r.p.m. and spring loaded to exert a 32-lb. load. The set-off tendency of a carbon is determined by passing between the rolls a standard "sandwich" comprising of two pieces of white test paper with an interleaved sample of test carbon paper. The intensity of the pattern obtained on the white test paper provides the basis for evaluation by using a densitometer or by visual comparison.

Extensive experience in evaluating the intensity of "set-off" patterns of a wide range of one-time carbons by densitometric and visual means clearly established that a very precise and simplified control could be effected by using visual comparisons.

This test method will also show the presence of pinholes and coating imperfections of either semi- or full-coated carbon papers in one pass through the machine.

Originally conceived as a laboratory test model, the carbon paper tester now functions as an essential and effective quality control instrument in the carbon paper industry. It has been accepted by the manufacturers as a valuable tool to assist them in meeting specifications and manufacturing quality.

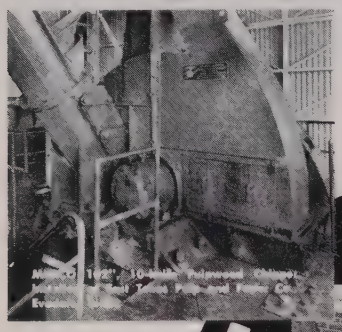
Exhibits

During the Eleventh Testing Conference an exhibit of testing equipment for pulp and paper was open to everyone in attendence. This exhibit was sponsored by the exhibitors committee of the Testing Division and was planned by W. F. Bachelder, Testing Machine, Inc., Mineola, N. Y., chairman.

The following companies participated:

Coulter Industrial Sales Co., Elmhurst, Ill.
Custom Scientific Instruments, Inc., Kearny, N. J.
Du Bois-Webb Co., Detroit, Mich.
Eberbach & Son, Ann Arbor, Mich.
Emerson Apparatus Co., Melrose, Mass.
W. & L. E. Gurley Co., Troy, N. Y.
Hart Moisture Meters, West Islip, N. Y.
Hunter Associates Laboratory, McLean, Va.

MURCO



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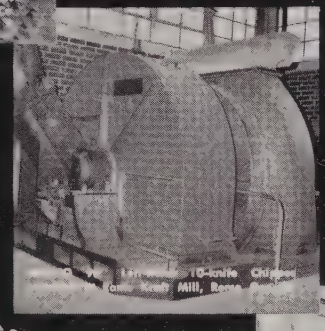
BETTER Cooking YIELD

New sound color movie of MURCO Chipper in operation available.
Write for appointment.

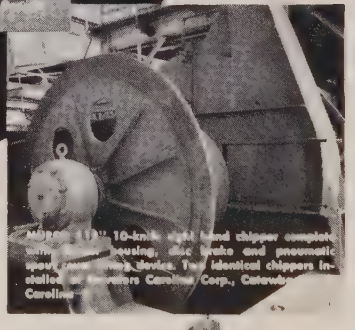


ROUND LOG
Pulpwood Chippers

- MADE IN DISC DIAMETERS FROM 36" TO 153"
- COMPACT, MURCO ROUND LOG PULPWOOD CHIPPERS REQUIRE LESS FLOOR SPACE.

MURCO Round Log Pulpwood Chippers are designed to include the most desirable features for today's production requirements . . . the result of long and careful study of the various features that contribute to outstanding chipper performance in producing more and better chips at less cost . . . less sawdust, fewer slivers, freedom from repairs yet at the same time having production records of 100 cords or more per hour. The MURCO heavy design constructio reduces vibration.

All backed by years of constant development so that each year results in an improved chipper design, the latest of which is MURCO UNI-CHIP that produces more uniform chips with less bruising. MURCO UNI-CHIP is furnished "when specified" on all new MURCO Chippers—or your present MURCO Chipper can be adapted to it.



MURCO 104" 12-knife chipper with Uni-chip knife mounting, 24" "V" spout, Blower housing-disc brake, spout cover lifting device. Motor synchronous 1250 H.P. 360 RPM. Motor coupled to chipper shaft with a flexible floating type coupling . . . unique design in that the coupling connection is on the end of the shaft. Installed at Tennessee River Pulp & Paper Co., Counce, Tennessee.

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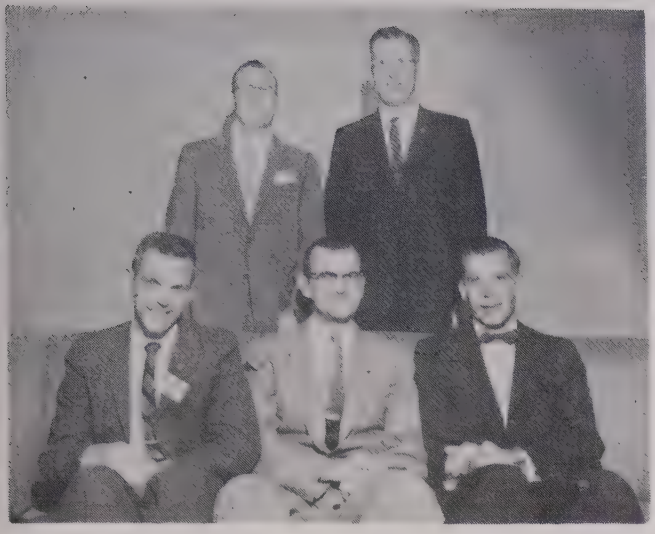

Water Session: E. W. Petrich, Howard Paper Mills, Inc., moderator; R. W. Purdy, Michigan Water Resources Commission, R. K. Bamman, Champion Paper and Fibre Co. Standing: W. A. Flower, Howard Paper Mills, Inc., M. H. Borland, The Mead Corp.

Hygrodynamics, Inc., Silver Spring, Md.
Hygrotester, Inc., Brooklyn, N. Y.
Instron Engineering Co., Canton, Mass.
Lord & Schoenberg, Cleveland, Ohio.
Macbeth Daylighting Co., Newburg, N. Y.
Manufacturers Engineering & Equipment Corp., Hatboro, Pa.
Martin Sweets, Inc., Louisville, Ky.
Robbins Instrument Co., Inc., New York, N. Y.
J. O. Ross Engineering Division of Midland Ross Corp., New York, N. Y.
Testing Machines, Inc., Mineola, N. Y.
Thwing-Albert Instrument Co., Philadelphia, Pa.
Welch Manufacturing Co., Chicago, Ill.
Williams Apparatus Co., Watertown, N. Y.

Mill Visits

On Friday Sept. 30, 1960, many of the delegates to the Eleventh Testing Conference took advantage of the opportunity to visit the KVP or the Sutherland mills of the KVP-Sutherland Paper Co. in Kalamazoo.

Twelfth Testing Conference

The Twelfth TAPPI Conference will be held Aug. 15–18, 1961, at the Queen Elizabeth Hotel, Montreal, Que.

Last Session: J. R. Gunning, Abitibi Power & Paper Co., moderator; E. Werle, Carling & Co.; L. E. Georgevits, The Borden Co.; C. A. Bicking, The Carborundum Co. Standing: A. A. Robertson, Pulp & Paper Research Inst. of Canada, D. S. Dixler, Air Reduction Co.

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AHCO defoamers, paste and liquid, form stable emulsions. They can be added directly from drums or from stock emulsions, and are effective under varying conditions of temperature and pH. All have FDA extensions.

FOR PAPER MACHINE SYSTEMS

AHCO offers liquid and paste defoamers with FDA extensions. They are easily emulsified in soft or hard water and form stable emulsions. AHCO defoamers will not adversely affect sizing; are suited to a wide range of pH conditions.

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TAPPI NOTES

APPA and TAPPI

TAPPI's objects and activities are closely related to those of other engineering and technical societies and other paper industry associations. Frequently this community of interests has led to programs undertaken jointly by several associations, resulting in broader, more effective action than could be realized through single sponsorship. The benefits of such cooperation are nowhere better illustrated than in those activities jointly undertaken by TAPPI and the American Paper and Pulp Association.

As the paper industry's trade association APPA is actively interested in many operations which do not directly concern TAPPI as a technical society. In addition, however, there are many areas—production, technical, and research—in which both APPA and TAPPI have a common interest and responsibility. It is in these areas that jointly sponsored programs have proved to be mutually beneficial to both associations.

TAPPI was organized in 1915 as a section of the American Paper and Pulp Association. A year later at its first annual meeting the section was renamed the Technical Association of the Pulp and Paper Industry and formally established as an independent association. The annual meetings of both associations continued to be held together until the growing attendance at both meetings made this arrangement impractical. For many years the TAPPI staff occupied offices in the APPA headquarters until the space limitations there led to moving the TAPPI offices to a separate location in 1953. Thus both literally and figuratively the APPA and TAPPI staffs have worked closely together for many years.

Even more important, many of TAPPI's leaders have been equally active in APPA assignments, and these dual responsibilities have provided effective coordination of individually sponsored programs. This liaison has been particularly evident in the work of the APPA Technical Committee, whose membership includes the TAPPI president, vice-president, and executive secretary. Last year this committee was renamed the APPA Technical Policy Committee to emphasize further its responsibilities as a policy group and to prevent possible confusion with various TAPPI committees.

The APPA Technical Policy Committee is one of the older standing committees of the American Paper and Pulp Association. For approximately twenty-five years it has been concerned with the programming, administration, and review of association activities and problems in the technical, manufacturing, and affiliated fields. The detailed implementation of its continuous programs has been carried forward by four subcommittees: a Committee on Coordination of Research, a Committee on Biological Control, a Committee on Classification and Definitions, and a Committee on Instrumentation Research.

The APPA Committee on the Coordination of Research is responsible for the dissemination of information on paper industry research projects, the stimulation of research interest in the scientific problems of the paper industry, and the enhancement of the prestige of the paper industry in the scientific life of the nation. Every two years the committee compiles and publishes a report "Research Projects in the Pulp and Paper Industry," which lists and describes briefly the fundamental and applied research projects of interest to the industry which are being pursued in various colleges, universities, technical schools, government agencies, and other research institutions engaged in research activities of public record. A companion publication "Some Fundamental Research Problems of the Pulp and Paper Industry," has also been prepared to acquaint educators with areas in the paper industry where research effort might be fruitful.

A relatively new activity of the committee has been the sponsorship of an annual research conference to bring together scientific representatives of the various colleges and universities and research personnel of the paper industry for the purpose of discussing fundamental research problems of interest to the industry. During the last two years these research conferences have been jointly sponsored by the APPA Committee on the Coordination of Research and the TAPPI Fundamental Research Committee. These meetings have proved to be an effective means of arousing interest in the paper industry and in the application of various scientific disciplines to the industry's problems.

The APPA Committee on Biological Control is concerned with sanitary standards and the use requirements of paper and paperboard employed in the packaging of foods and in other fields where sanitation or public health is involved; also it is continually developing information useful to the entire industry in its efforts to control the various bacteria and fungi which are responsible for slime or which otherwise affect and interfere with manufacturing efficiency. The committee is responsible for the evaluation of a wide variety of biostatic agents suggested for slime control use in the paper industry. A regular screening program is maintained, under which some 20 to 30 compounds are investigated annually for inhibiting concentrations against two species each of bacteria and fungi. The results are made available to all APPA members and are then published in *Tappi*. The committee has also undertaken a study of the effect of various pulps on the bioactivity of slime agents. A further activity is a critical revue of all literature pertinent to the microbiology of pulp and paper, the results of which are distributed widely to the industry at five-year intervals. The Committee on Biological Control has many times in the past been concerned with sanitary standards and the use requirements of

paper and paperboard in the packaging of foods and in other fields where sanitation and public health is involved. With the advent of recent activity following amendments to existing food and drug legislation an APPA Committee on Chemical Additives has been created to deal specifically with the matter of chemical additives and to represent the paper industry in the current situation.

The APPA Committee on Classification and Definitions has been primarily concerned with the preparation and publication of the 1940 and 1951 editions of the "Dictionary of Paper." Work is presently under way to publish a third edition, and the committee has been enlarged to represent all phases of the industry including the graphic arts and converting fields. In addition to the revision of the dictionary, the committee has been presented occasionally with special problems of classification and interpretation. The American Standards Association in its capacity as United States member body representative in the 37 nation International Organization for Standards (ISO) has received guidance in its projects on the definition of paper and paper processing terms.

The APPA Committee on Instrumentation Research has been responsbile for supervising the instrumentation studies at The Institute of Paper Chemistry. As a result of this program, now in its twenty-fifth year, over 122 reports have been distributed, each dealing with a study of the character, accuracy, efficiency, precision, and reliability of an instrument employed by or offered by this industry and its consumers. These instrumentation reports have achieved an international status and are widely accepted, both by the users and the instrument builders.

During the last few years the Instrumentation Research Committee has given considerable attention also to the matter of calibration of some of the more widely used test instruments. In this field the APPA Instrumentation Research Committee and TAPPI have enlisted the cooperation of the National Bureau of Standards. The Bureau has undertaken to provide, on a modest fee basis, standard specimens of paper for calibration of tearing-strength instruments under proper conditions. Members of the Instrumentation Research Committee and TAPPI representatives are serving in an advisory capacity to aid the Bureau in the development of the calibration procedure for the tearing strength tester. It is hoped that standard test specimens will be available shortly which, when used with an acceptable calibration procedure now being worked out, will meet the need for a means by which tearing strength testers may be kept in more reasonable agreement. If this type of program is successful, it will be extended stepwise to other test instruments. A joint APPA–TAPPI Reference Materials Committee has been established to guide these studies.

Other recent examples of APPI–TAPPI collaboration are the Paper Industry Research Forum held at the 1959 Annual Meeting, the past work of the APPA Community Relations Committee and some TAPPI local sections, and the present Paper Industry Career Guidance Committee (whose activities were described in "TAPPI Notes" in the June, 1960, issue of *Tappi*). Such programs have demonstrated the substantial advantages of joint efforts to TAPPI members, to the paper industry, and to the associations involved. TAPPI looks forward with enthusiasm to similar opportunities for such cooperative efforts in the future.

PHILIP E. NETHERCUT
Executive-Secretary

Change of Date

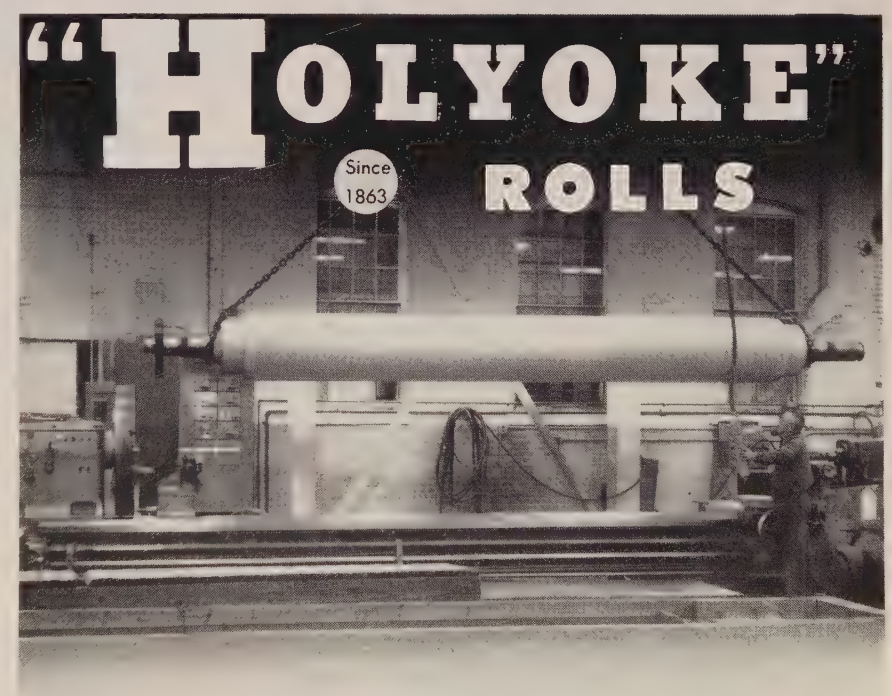
Eleventh Corrugated Containers Conference

Sept. 6–8, 1961

instead of

Sept. 11–13, 1961

St. Francis Hotel, San Francisco, Calif.



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TAPPI PROFILES

Walter C. Bloomquist

Walter C. Bloomquist, a member of the Executive Committee, was born in Chisolm, Minn., in the heart of the Mesabi Iron Range. He completed his high schooling there and then went to the University of Minnesota from which he graduated with a B.S. degree in electrical engineering in 1932, an M.S. in 1934, and a Bachelor of Business Administration in 1935. In 1950, he received the professional degree of E.E.

His college summers were spent working in the scenic Rockies. Having spent one summer in Yellowstone National Park doing photo work, he spent the next four in Glacier National Park operating the power plant for the Glacier Park Hotel. He also interrupted his college education for one year to work as a locomotive fireman and a mining drilling operator in Chisholm.

He went to work for General Electric straight from college, in 1935, and has been with the company ever since. First in Schenectady, N. Y., then in Lynn, Mass., and now in Philadelphia, Pa., he has worked in various branches of design and application engineering, and engineering management.

Since 1955, he has been Manager of Application Engineering, Atlantic District, Philadelphia, Pa.

In 1937, he was the company's "guarantee" engineer on the submarines *U.S.S. Perch*, *U.S.S. Pickerel*, and *U.S.S. Permit*, the first submarines built by the United States after World War I. In them he sailed for more than 20,000 miles, but not wholly without mishap. One time, on a trial run off Cape Canso, Nova Scotia, his submarine hit a submerged rock and had to send and S.O.S.; another time, during a test crash dive, the bow plane fins stuck in the "dive" position and the ship did not straighten out until it scraped bottom.

Walter Bloomquist has been a member of TAPPI since 1947. Since presenting a paper at the first Engineering Division Conference in Milwaukee, Wis., in 1946, his efforts in the Association activities have been concentrated on the Engineering Division. In 1952, he became the Division Secretary and held this office until 1955. In recognition of the services he rendered to the pulp and paper industry through the administration of TAPPI activities the Engineering Division presented him with a Citation. At the Engineering Conference in Philadelphia, in 1954, he took part in a radio program, "Meet the Engineer"; the subject: What TAPPI Means to Me.

He is past secretary of the Steam and Power Committee (1949–1951) and is now secretary of the Staff Advisory Committee of the Division.

Besides being a member of the Engineering Division he is also a member of the Executive Committee, Project Appropriations Committee, Membership Services Committee, and the Publications Committee (formerly Publications Management Committee). In October, 1959, he and R. G. Macdonald, Treasurer of the Association, represented TAPPI at the founding of the Italian Section, in Lake Como, Italy.

Interested in the work of many pulp and paper industry organizations, he was co-chairman (1956) of the Power Sessions of the American Pulp and Paper Mill Superintendents Association at Lake Placid, N. Y., and is an affiliate member of the Canadian Pulp and Paper Association.

He is a Fellow of the AIEE and is and has been very active in various local and national committees: Locally he was a member of the Philadelphia Section Executive Committee, its treasurer, and continues in its Educational Committee work.

Other professional societies of which he is a member are the ASME and the NSPE; and he is a registered professional engineer. He was treasurer of the National Power Conference in 1960.

Another organization in which he is active is The Engineers' Club of Philadelphia. He conceived, organized, and directed its courses on industrial power distribution. These have also been offered in other cities.

He was the General Electric Company's representative on the Baltimore Association of Commerce Committee to evaluate a nuclear research reactor proposal.

A versatile engineer and an expert on industrial turbine generation, electric power distribution, and capacitor applications—his M.S. thesis was on the economics of process steam and electric power generation—he has strongly promoted the education programs of professional societies as well as those of the General Electric Co., and has taught courses ranging from elementary principles of electricity to nuclear power.

Besides teaching he has given over 100 talks to technical and professional groups, published over 50 papers, and is a contributing author to three books. He is editor and the principal author of "Capactors for Industry"; the author of Section 16 in "Kents Mechanical Engineers Handbook—Power," and the author of Chapter 8 in "Industrial Power Systems Handbook."

Scouts, schools, and University Alumni Association are among some of his civic activities. In Schenectady, he helped organize Scout Troops and was president of its University of Minnesota Alumni Association. At present, he is treasurer of the International Student Fund at Radnor High School.

His hobbies are 35 mm. photography (strictly amateur) and his workshop. He also enjoys traveling for pleasure, but since so much is done on business he hesitates to claim it as a legitimate hobby.

Mrs. Bloomquist is the former Loretta Koelfgen of Minneapolis, Minn. They have two sons, Allan (17) and Douglas (19).

Twelfth

Coating Conference

TAPPI

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May 8–10, 1961

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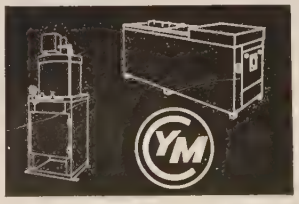

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ASSOCIATION REVIEW—1960

THE following report gives the highlights concerning activities of the Technical Association of the Pulp and Paper Industry in 1960.

Membership

There were 1031 individual members elected in 1960: 552 members resigned or were dropped from the membership. On Dec. 31, 1960, the total individual membership was 10,103.

There were six corporate members elected in 1960. The membership of 13 corporate members was terminated. The corporate membership of Dec. 31, 1960 was 261.

The following companies became corporate members in 1960:

A. C. I. Fibre Packages Pty., Ltd., Auckland, N. Z.
Armstrong Cork Co., Lancaster, Pa.
Caribbean Container Co., San Juan, P. R.
Harding-Jones Paper Co., Excello, Ohio
Packaging Corp. of America, Grand Rapids, Mich.
Steiner Co., Chicago, Ill.

There were 10 sustaining members elected in 1960: 13 sustaining members resigned. The sustaining membership on Dec. 31, 1960 was 259.

The following companies became sustaining members in 1960:

Abbe Engineering Co., New York, N. Y.
Armco Steel Co., Middletown, Ohio
Jackson & Moreland, Inc., Boston, Mass.
Keever Starch Co., Columbus, Ohio
Pope and Evans, New York, N. Y.
Robbins Instrument Co., Inc., New York, N. Y.
Southworth Machine Co., Portland, Me.
U. S. Movidyn Corp., Chicago, Ill.
Vermont Kaolin Corp., Bristol, Vt.
Carl Zeiss, Inc., New York, N. Y.

Necrology

The Association lost the following members through death in 1960:

Norman F. Allemore, St. Joe Paper Co., Port St. Joe, Fla.
E. Clinton Bowen, The Bowen Corp., Cambridge, Mass.
C. E. Buchan, Electric Machinery Mfg. Co., Minneapolis, Minn.
William Carter, Canadian Ingersoll-Rand Co., Ltd., Montreal, Que.
Charles H. Champion, R. T. Vanderbilt Co., New York, N. Y.
Fred L. Chappell, Hercules Powder Co., Kalamazoo, Mich.
Lester W. Crouse, Penick & Ford, Ltd., Springfield, Mass.
Francis J. Curtis, Monsanto Chemical Co., St. Louis, Mo.
Manley W. Davis, Sherbrooke Machineries, Ltd., Montreal, Que.
Jorge Diena, Pamer S. A., Montevideo, Uruguay
John Paul Ekberg, retired, Riverside, Conn.
Harry D. Eliason, Cellulose Sales Co., La Jolla, Calif.
Taro Fuchida, Sanko Paper Mfg. Co., Ltd., Osaka, Japan
George Hammer, Forbes Lithographing Co., Boston, Mass.
Lewis Hebbs, Cross & Beven, Arlesey, Bedfordshire, England
Joseph B. Homan, A. E. Staley Mfg. Co., Decatur, Ill.
Gordon I. Hoover, Provincial Paper Co., Thorold, Ont.
Harry Jansen, Simpson Paper Co., Everett, Wash.
O. C. William Johnson, Johnson, Jorgenson & Wettre, Ltd., London, England
Arthur E. Jones, Oxford Paper Co., Rumford, Me.
Marvin C. Jones, Lockport Felt Co., Newfane, N. Y.
Francis I. Kittredge, General Electric Co., Philadelphia, Pa.
William L. Kraft, Bulkley, Dunton Pulp Co., Inc., New York, N. Y.
Clement A. Malyska, Owens-Illinois Glass Co., Chicago, Ill.
Julian W. Maxson, Maxson Automatic Machinery Co., Westerly, R. I.
William H. Mordo, Stowe-Woodward, Inc., Newton Upper Falls, Mass.
Humphrey D. Murray, Ozalid Co., Ltd., Loughton, Essex, England
Marcy B. Newell, Ecusta Paper Co., Pisgah Forest, N. C.
Reuben B. Robertson, Jr., Champion Paper & Fibre Co., Hamilton, Ohio
John V. Roslund, Manufacturers' Agent, Portland, Ore.
Paul Ruesch, Meypro N. V., Zaandam, The Netherlands
J. Keith Russell, Lignosol Chemicals Ltd., Quebec, Que.
Lloyd T. Sandborn, The Crossett Co., Crosset, Ark.
Miss Julia Saunders, Enoch Pratt Free Library, Baltimore, Md.
Yosizo Shimamura, Kokusaku Pulp Ltd., Co., Tokyo, Japan
George Trudeau, Holyoke Machine Co., Holyoke, Mass.
Joseph Velardi, Rayonier, Inc., Fernandina Beach, Fla.
Edward H. Voightman, Kimberly-Clark Corp., Neenah, Wis.
John E. A. Warner, retired, Milford, Conn.

Publications of the Association

Tappi

Tappi, the monthly magazine of the Association, completed its twelfth year of publication. In 1960 there were 1040 pages published in the technical section. This compared with 1016 pages in 1959 and 816 pages in 1958. The total number of pages published was 3872 in contrast to 3296 in 1959. The circulation of the magazine made a substantial increase. There were 1170 pages of advertising run in 1960 in contrast with 1065 pages in 1959.

Bibliography of Papermaking and U. S. Patents—1959

One cloth-bound issue of the Bibliography of Papermaking and U. S. Patents (720 pages) was issued in 1960. It was prepared by the staff of The Institute of Paper Chemistry, Appleton, Wis.

College Textbook

During 1960 the College Textbook of Pulp and Paper Manufacture was printed as a single volume, replacing a two-volume set. The book was again printed by the photo offset process and many typographical errors were corrected. The text has been used in the colleges offering pulp and paper courses. Many corrections and suggestions have been received. C. E. Libby, formerly professor at North Carolina State College, now retired, has been employed to edit and revise the entire text. It is expected that by the fall of 1962 a letterpress printed book between hard covers will be ready for use by the colleges. The work of preparing the college textbooks has been carried on under the sponsorship of the Training and Education Committee.

Monographs

Monograph No. 21, "Mechanical Pulping Manual" was issued. It was prepared under the direction of the Mechanical Pulping Committee of the Pulp Manufacture Division. Earl H. Johnson, Stevens & Thompson Paper Co., Greenwich, N. Y., was editor.

Special Reports

One Special Report was issued in 1960:
No. 428. "Dandy Roll Practices"

Standards, Suggested Methods

In 1960 one new tentative standard was approved: T 489 m "Stiffness of Paperboard"; one new suggested method: T 491 m "Water Immersion Test for Paperboard"; five official

standards were revised; and five tentative standards were revised. Further details appear in the report of the Standards Committee James d'A. Clark, chairman.

Data Sheets

Eight new data sheets were published in 1960.
No. 202. Approximate Requirements for Electric Power in Pulp Bleaching
No. 203. Roll Storage Capacities and Floor Loading
No. 204. Flow Process Symbols
No. 205. Digester Design
No. 206. Winder Drive Power Requirements—Mean of Experience Values
No. 207. Winder Drive Power Requirements
No. 208. Winder Generator Power Requirements
No. 209. Recommended Voltage Levels for A. C. Polyphase Motors

In addition, the following data sheets have been reviewed and have been withdrawn because the information is obsolete, erroneous, or not practical: Nos. 70, 75, 127B, 145A-1, 196, 8A, 8B, 78, 78A, 174, and 117.

TAPPI Medal Awards

The 28th TAPPI Medal for outstanding contributions to the technical advancement of the paper industry was awarded to Louis E. Wise of The Institute of Paper Chemistry, Appleton Wis. The presentation was made by Harry F. Lewis, vice-president of the Institute.

Employment

The Association continued to assist the industry in its search for new technical employees. In cooperation with the APPA, NPA, PIMA and NPTA, it continued to take an aggressive interest in the career guidance program of the industry. In addition, a special service was continued at the Association annual meeting; the establishment of an employment exchange in which a room was set aside to house job descriptions that permitted members to know where employment opportunity existed.

Headquarters Office

The Association offices, now located at 360 Lexington Ave., New York, N. Y., were visited by many members and were used to hold a number of committee meetings. James W. Field resigned late in the year as Local Section Assistant and joined the staff of the Packaging Institute.

Local Sections

Two new local sections were chartered in 1960, the Golden Gate and St. Louis Sections. The New England Section established three districts: Bay (Eastern), Pioneer Valley (Central), and Berkshire (Western). The Section is now organized in a manner similar to the Empire State Section.

The chairmen of local sections elected in 1960 were:

Chicago—Carl M. Helm, American Cyanamid Co., Chicago, Ill.
Delaware Valley—Alfred I. Saindon, Jr., Curtis Paper Co., Newark, Del.
Empire State—John C. Rice, Lowe Paper Co., Ridgefield, N. J.
Metropolitan District (E. S.)—Francis R. Marchetti, Titanium Pigment Co., New York, N. Y.
Northern District (E. S.)—John L. Hudson, Jr., Crown Zellerbach Corp., Carthage, N. Y.
Central District (E. S.)—Bert L. Channer, H. Waterbury Sons, Oriskany, N. Y.
Western District (E. S.)—Edward F. Andrews, International Paper Co., Niagara Falls, N. Y.
Eastern District (E. S.)—Richard Collins, Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.
Golden Gate—H. W. Theller, Crown Zellerbach Corp., San Francisco, Calif.
Gulf Coast—William Elsevier, International Paper Co., Mobile, Ala.
Italian—Pierre Bersano, Cartiere Burgo, Torino, Italy
Kalamazoo Valley—W. L. Kite, Simpson Lee Paper Co., Vicksburg, Mich.
Lake Erie—Thomas R. McMonagle, Interchemical Corp., Cleveland, Ohio
Lake States—William R. Nelson, Green Bay Paper & Pulp Co., Green Bay, Wis.
Maine-New Hampshire—Edward N. Poor, Hudson Pulp and Paper Co., Augusta, Me.
New England—John Lewis, Pulp and Paper Research Center, Inc., Lawrence, Mass.
Bay District (N. E.)—John W. Wendell, Jr., Tileston & Hollingsworth Co., Boston, Mass.
Berkshire District (N. E.)—Frederick S. Klein, Byron Weston Co., Dalton, Mass.
Pioneer Valley District (N. E.)—Alex. E. Hutton, Fitchburg Paper Co., Fitchburg, Mass.
Ohio—Charles S. Sweitzer, Diamond National Corp., Lockland, Ohio
Indiana District—Charles E. Eberly, Paper Art Co., Indianapolis, Ind.
Pacific—P. T. Dickie, Crown Zellerbach Corp., West Linn, Ore.
St. Louis—W. J. Rice, Central States Paper & Bag Co., St. Louis, Mo.
Southeastern—R. A. Flick, Brunswick Pulp & Paper Co., Brunswick, Ga.
Virginia-Carolina—Roy F. Traver, Union Bag-Camp Paper Corp., Franklin, Va.

Certificate of Appreciation

The following members received certificates of appreciation in recognition of their services to the Association as division, section or committee chairmen:

Division and Committee Chairmen

W. H. Aiken—Paper and Paperboard Group
K. A. Arnold—Paper Shipping Sack Testing Committee
M. W. Block—Corrugated Containers Raw Materials Committee
W. D. Boggess—Deinking Committee
R. W. Buttery—Corrugated Containers Production Committee
T. W. Carroll—Corrugated Containers Industrial Engineering Committee
Myron J. Clark—Container Testing Committee
R. Q. Connor—Maintenance Engineering Committee
P. J. Frost—Acid Pulping Committee
F. B. Grunwald—Agricultural Fibers Committee
J. R. Gunning—Routine Control Methods Committee
S. G. Holt—Drying Committee
R. C. Hutcheson—Corrugated Containers Engineering Committee
Morris W. Kane—Wax Testing Committee
R. V. Knapp—Steam and Power Committee
B. Mendlin—Corrugated Containers Division
W. H. E. Neuss—Adhesives Testing Committee
E. H. Olmstead—Staff Advisory Committee, Engineering Division
V. P. Owens—Engineering Division
J. K. Powell—Process Instrumentation Committee
G. T. Renegar—Cylinder Board Committee
H. W. Seibel—Corrugated Containers Process and Quality Control Committee
Horace A. Spencer—Plastics Laminates Committee
H. A. Stoess, Jr.—Industrial Engineering and Materials Handling Committee
W. Utschig—Paperboard Testing Committee
W. M. Van Horn—Microbiological Committee
Romulus S. von Hazmburg—Structural Fibrous Materials Committee
Anthony J. Yankowski—Mechanical Pulping Committee

Local Section Chairmen

George K. Boger, Jr.—Delaware Valley Section
John C. Boynton—Lake Erie Section
Andrew J. Chase—Maine-New Hampshire Section
Richard R. Chase—Southeastern Section
Henry J. Klauke—Chicago Section
William O. Kroeschell—Kalamazoo Valley Section
Robert L. Leaf, Jr.—Lake States Section
Norval Magnusson—Pacific Section
Ross F. Miller—Virginia-Carolina Section
Frederic W. O'Neil—Empire State Section
Virgil E. Perry—Ohio Section

Mexican Association

In June, 1960 R. G. Macdonald, treasurer and editorial director of the Association, visited Mexico City and assisted

the people in the pulp and paper industry of Mexico to form a national technical association. The industry is exceptionally well endowed with a large number of highly qualified technical, operating and managing executives. The new organization was formerly organized in August, 1960 as the Asociacion Mexicana de Tecnicos de las Industrias de la Celulosa y Papel A.C. Its first president is Adalberto Tirado A., superintendent of Fabrica de Celulosa y Papel Loreto y Pena Pobre.

Committee Projects

During 1960 the Association made committee project grants amounting to $54,801. A detailed report concerning these projects are included in the reports of the Project Appropriation Committee to appear in *Tappi*.

Meetings of the Association

In addition to the Annual Meeting, the Association held 11 functional conferences during 1960. The details concerning these meetings have been published in *Tappi* during the year.

1960 Annual Meeting

The 45th Annual Meeting of the Association was held at the Commodore Hotel, New York, N. Y., on Feb. 22–25, 1960. An attendance of about 3015 persons were registered and 102 papers were presented at the technical sessions. The annual luncheon was featured by the presentation of the TAPPI Medal to Louis E. Wise, professor at The Institute of Paper Chemistry. The presentation was made by Harry F. Lewis, also of the Institute.

Eleventh Coating Conference

The Eleventh Coating Conference was held at the Edgewater Beach Hotel, Chicago, Ill., on May 23–25, 1960. There were 957 registrants at the meeting, the largest registration to date. Fourteen papers were presented. One panel symposium featured "Coating for Printing." R. W. Hagemeyer of Wyandotte Chemicals Corp., Wyandotte, Mich., was general chairman of the conference. R. W. Martinek of Kimberly-Clark Corp., Neenah, Wis., was program chairman and C. W. Cairns of Dow Chemical Co., Midland, Mich., was local arrangements chairman. Bert Cremers, vice-president of Wyandotte Chemicals Corp. was the luncheon speaker. His subject was "Changes in Marketing Patterns-Opportunities for Technical Men." A plant tour was made following the meeting, of the Beloit Iron Works plant at Beloit, Wis. The tour featured the new Beloit research laboratory and the experimental coater. There was a general inspection of the plant and its facilities. Fourteen paper were presented at the conference.

First Pulp Bleaching Conference

The First Pulp Bleaching Conference was held at the Edgewater Beach Hotel, Chicago, Ill., on June 14–16, 1960. There were 301 registrants. One of the purposes of the conference was to review the subjects covered in TAPPI Monograph No. 10 on "Bleaching of Pulp." The committee in its program of revising this book felt that a forum would strengthen the effectiveness of the subject coverage. Ferdinand Kraft of The Marathon Division of American Can Co., was general chairman. R. J. Auchter of Kimberly-Clark Corp. Neenah, Wis., was chairman of the program committee and was assisted by J. D. Wethern, Riegel Paper Corp., Acme, N. C.; J. F. Whalen, Combined Locks Paper Co., Combined Locks, Wis.; and F. P. Doane, Jr., Bergstrom Paper Co., Neenah, Wis. The program featured an international panel on "Progress in Pulp Bleaching," moderated by R. P. Whitney, The Institute of Paper Chemistry, Appleton, Wis. There were 17 papers presented.

Ninth Statistics Course

The Ninth Pulp and Paper Statistics Course was jointly sponsored by TAPPI and the CPPA Technical Section and was held at Brevard College, Brevard, N. C., starting Aug. 8, 1960, and ending Aug. 19, 1960. A total of 30 students registered for the course (19 basic and 11 advanced). Group visits were made to the mills of Olin Mathieson Chemical Co., Ecusta Paper Div., Pisgah Forest, N. C., and to the Champion Paper & Fibre Co., Canton, N. C. The course was a workshop type of program under the direction of a teaching staff consisting of R. J. Hader, Institute of Statistics, North Carolina State College, Raleigh, N. C.; A. H. E. Grandage, same; C. E. Noble, Kimberly-Clark, Corp., Neenah, Wis.; M. S. Renner, Dewey & Almy Chemical Corp., Cambridge, Mass.; and A. E. Paull, Abitibi Power & Paper Co., Ltd., Toronto, Ont., Canada.

Fourteenth Alkaline Pulping Conference

The Fourteenth Alkaline Pulping Conference was held at the Multnomah Hotel, Portland, Ore., on Aug. 22–24, 1960. There were 387 men registered. During the meeting there was a program sponsored by the Sulfite Pulping Committee. (This committee was established recently as a merger of the Acid Pulping Committee and the Semichemical Pulping Committee. David Wetherhorn of Continental Can Co., Savannah, Ga., was general chairman of the conference. A. H. Wickett of Weyerhaeuser Co., Longview, Wash., was chairman of the arrangements committee. P. H. West of Thilmany Pulp and Paper Co., Kaukanna, Wis., was program chairman.

The banquet speaker was Derrick B. Currie of the Weyerhaeuser Co., Longview, Wash. whose talk was "Some Thoughts on Leadership." Three visits were arranged to the mills of Longview Fibre Co., Longview, Wash.; Crown Zellerbach Corp., Camas, Wash.; the Pennsalt Chemicals Co., Portland, Ore.; the Electric Steel Foundry Co., Portland, Ore.; and the lumber mill of the Weyerhaeuser Co., Longview, Wash. There were 12 papers presented together with a panel on "High Yield Kraft Pulping."

First Forest Biology Conference

The First Forest Biology Conference was held at the New Washington Hotel, Seattle, Wash., in Aug. 24–27, 1960. There were 65 registrants. R. J. Seidl of Simpson Timber Co., Seattle, Wash., was general chairman. J. W. Duffield of W. B. Greeley Forest Nursery, Nisqually, Wash., was chairman of the arrangements committee. The theme of the meeting was "Better Fibers from Better Trees Through Forest Biology." There were 11 papers presented. Field trips were made to the Col. W. B. Greely Forest Nursery, Perpetual Forests, Inc., Seed Orchard, Grand Mount, Wash.; and the Mauning Seed Co., Roy, Wash.

Eleventh Testing Conference

The Eleventh Testing Conference was held at the Civic Auditorium, Grand Rapids, Mich., on Sept. 27–29, 1960. There were 275 registrants. W. H. Aiken of Personal Products Co. Milltown, N. J., was general chairman. W. R. Willets of Titanium Pigment Co., New York, N. Y., was program chairman and C. E. Jakeway, Packaging Corp. of America, Grand Rapids, Mich., was local arrangements chairman. Twenty papers were presented. Twenty one companies exhibited testing equipment. Inspection visits were made to the mills of KVP-Sutherland Paper Co., in Kalamazoo, Mich. An important feature of this conference was the meeting of the committees of the Testing Division wherein testing standards were discussed. There was a symposium on "Relative Humidity and Paper Test Methods" and also a symposium on "Water" moderated by E. W. Petrich of Howard Paper Mills, Urbana, Ohio.

Fifth Deinking Conference

The Fifth Deinking Conference was held at the Conway Hotel Appleton, Wis., on Oct. 5–7, 1960. There were 145 registrants. The general chairman of the conference was

J. D. Allen, Bergstrom Paper Co., Neenah, Wis. M. R. Kinne, Sealright-Oswego Falls Corp., Fulton, N. Y., was program chairman. Two symposiums were held on "Economics of Deinking" and "The Future of Deinking." The banquet speaker was D. W. Bergstrom of Bergstrom Paper Co., Neenah, Wis., who discussed "This Waste Paper Business." A tour was made of the facilities of The Institute of Paper Chemistry in Appleton, Wis.

Tenth Corrugated Containers Conference

The Tenth Corrugated Containers Conference was held at the Royal York Hotel, Toronto, Ont., Canada, on Oct. 10–13, 1960. The meeting was sponsored jointly by the TAPPI Corrugated Containers Division and the Corrugated Containers Committee of the CPPA Technical Section. The chairmen of the sponsoring organizations were B. Mendlin of Cornell Paperboard Products Co., Milwaukee, Wis., and R. H. McGee of Bathurst Power & Paper Co., Ltd. Montreal, Canada. There were 438 registrants, including 115 persons from Canada and one person from Australia. Thirteen papers were presented. Three plant visits were arranged to Hinde & Dauch, Ltd., Etobicoke, Ont.; Bathurst Containers, Ltd., Hamilton, Ont.; and Hygrade Containers, Ltd., Rexdale, Ont. A feature of the meeting was the presentation of a sound film "Operation of a Printer Slotter" which was produced under the direction of G. R. Wilmer of Packaging Corp. of America, Grand Rapids, Mich.

Fifteenth Plastics-Paper Conference

The Fifteenth Plastics-Paper Conference was held at the Syracuse Hotel, Syracuse, N. Y., on Oct. 17–19, 1960. There were 427 registrants. V. T. Stannett, New York State College of Forestry, Syracuse, N. Y., was general chairman. R. W. Loheed of Chas. T. Main, Inc., Boston, Mass., was program chairman and C. G. Morse of Sealright-Oswego Falls Corp., Fulton, N. Y., was local arrangements chairman. Eighteen papers were presented. Visits were made to the College of Forestry, Syracuse, N. Y., and to the Dilts Division of Black-Clawson Co., Fulton, N. Y. There was a panel discussion of "Papermaking with Synthetic Fibers," moderated by T. A. Howells of The Institute of Paper Chemistry, Appleton, Wis. The banquet speaker was D. H. Davenport, Deputy Commissioner of Commerce of New York State, Albany, N. Y., whose theme was "The State and Industries' Role in Research."

Fifteenth Engineering Conference

The Fifteenth Engineering Conference was held at the Robert Meyer Hotel, Jacksonville, Fla., on Oct. 24–27, 1960. There were 926 registrants, the largest number to attend the Engineering Conference. There were 18 technical sessions at which 55 papers were presented and five panel sessions were held. The banquet speaker was Walter H. Finn of Combustion Engineering, Inc., Windsor, Conn., who discussed "Nuclear Power for Industry." The conference chairman was M. J. Osborne, Bowaters Southern Paper Corp., Calhoun, Tenn. The technical program chairmen were V. P. Owens, Combustion Engineering, Inc., Windsor, Conn., and G. E. Shaad, General Electric Co., Schenectady, N. Y. J. B. Peebles, Jr., General Electric Co., Jacksonville, Fla., was local arrangements chairman. Visits were made to the mill of Owens-Illinois Glass Co. and St. Regis Paper Co. in Jacksonville. Twenty-six students in the Jacksonville High Schools attended the conference as part of the Joe Berg Foundation program which enables outstanding high school students to attend technical conferences of this kind.

APPA-TAPPI Research Conference

A joint conference on research was sponsored by TAPPI and the APPA at the Hotel Northampton, Northampton, Mass., on Nov. 4–5, 1960. The purpose of the meeting was to bring together professors of chemistry, chemical engineering, forestry, and related subjects from a number of universities throughout the country with an approximately equal number of representatives of pulp and paper companies. A. W. Plummer, Hudson Pulp & Paper Co., S. Windham, Me., was general chairman. Addresses presenting the need for fundamental research in the industry were made to help science and engineering department people in the colleges to know about the opportunities that exist in the industry for fruitful research efforts.

Divisions and Committees

During 1960 the following changes were made in the division and committee structures:

In the Pulping Division the Acid Pulping Committee and the Semichemical Pulping Committee were merged to form the Sulfite Committee.

A Synthetic Fibers Committee was established in the Converting and Consuming Division.

A Release Papers Testing Committee was established in the Testing Division.

Coating and Graphic Arts Division. C. A. Morton, Alden Press, Chicago, Ill., became vice-chairman of the division. J. E. Wilber, St. Regis Paper Co., Carthage, N. Y., replaced Mr. Morton as division secretary.

In the coating committee, J. E. Wilber, succeeded J. T. Loomer, Continental Can Co., New York, N. Y., as chairman. C. G. Landes, Charlotte, N. C., succeeded Mr. Wilber as vice-chairman. F. Kaulakis, Consolidated Water Power & Paper, Wisconsin Rapids, Wis., succeeded Mr. Landes as committee secretary. R. W. Martinek, Kimberly-Clark Corp., Neenah, Wis., joined the coating council.

In the Graphic Arts Committee, L. E. DeLauter, West Virginia Pulp & Paper, Chicago, Ill., replaced J. M. Fetsko, Lehigh University, Bethlehem, Pa., as public relations officer.

Converting and Consuming Division. J. C. Pullman, American Cyanamid Co., New York, N. Y., succeeded R. C. Sturken, Frank W. Egan Co., Somerville, N. J., as general chairman of the division. K. W. Britt, Scott Paper Co., Chester, Pa., became division vice-chairman. A staff advisory committee was formed with the following members: R. W. Loheed, Chas. T. Main, Inc., Boston, Mass.; T. A. Howells, Institute of Paper Chemistry, Appleton, Wis.; W. E. Hardy, International Minerals & Chemicals Co., Skokie, Ill.; and R. C. Sturken, Frank W. Egan Co., Somerville, N. J.

A new Synthetic Fibers Committee was formed under the Chairmanship of R. A. A. Hentschel, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

In the Wet Strength & Interfiber Bonding Committee, C. S. Maxwell, American Cyanamid Co., Stamford, Conn., replaced K. W. Britt as Committee Chairman.

In the Plastics Laminate Committee, R. H. Doughty, Fitchburg Paper Co., Fitchburg, Mass., replaced H. A. Spencer, Knowlton Bros., Watertown, N. Y., as committee chairman. R. J. Seiler, Behr-Manning Co., Troy, N. Y., became vice-chairman. D. Gilmore, Brown Co., Berlin, N. H., became secretary, and G. Reidy, Deering Milliken Research, Spartanburg, S. C., became associate secretary.

Paper and Paper Board Division. In the Cylinder Board Committee, C. D. Coffman Chesapeake Paperboard, Baltimore, Md., replaced G. T. Renegar, Container Corp. of America, Philadelphia, Pa., as committee chairman.

In the Water Committee, R. J. Baker, Wallace & Tiernan, Inc., Belleville, N. J., replaced J. G. Patrick, West Virginia Pulp & Paper, Luke, Md., as committee chairman. H. M. McFarlane, Abitibi Power & Paper, Ontario, Canada, became committee vice-chairman. In the Structural Fibrous Materials Committee, W. H. McPherson, Minnesota & Ontario

Paper, International Falls, Minn., replaced R. S. von Hazmburg, United States Gypsum Co., Chicago, Ill., as committee chairman, and R. H. Neisel, Johns-Manville Products Corp., Manville, N. J., became committee secretary.

Corrugated Containers Division. J. J. Koenig, Gaylord Container Div., Crown Zellerbach Corp., St. Louis, Mo., succeeded B. Mendlin, Cornell Paperboard Products, Milwaukee, Wis., as chairman; R. W. Buttery, Bathurst Containers, Ltd., Montreal, Que., Canada, replaced Mr. Koenig as vice-chairman; and K. R. Martin, Forest Products Div., Olin Mathieson Chemical Co., West Monroe, La., succeeded W. P. Blamire, Packaging Corp. of America, Grand Rapids, Mich., as secretary.

In the Engineering Committee, A. Richardson, Gaylord Container Div., Crown Zellerbach Corp., St. Louis, Mo., succeeded Mr. Buttery as chairman; J. E. Knecht, Bathurst Power and Paper Co., Whitby, Ont., succeeded Mr. Richardson as vice-chairman; and L. W. Kutz, Reliance Electric and Engineering Co., Bala-Cynwyd, Pa., replaced R. C. Berger, General Electric Co., Schenectady, N. Y., as secretary.

In the Industrial Engineering Committee, R. S. Owen, R. S. Owen & Co., Chicago, Ill., replaced T. W. Carroll, Owens Illinois Glass Co., Toledo, Ohio, as chairman; F. H. Cloud, Packaging Corp. of America, Grand Rapids, Mich., replaced Mr. Owens as vice-chairman; and J. Sprague, Green Bay Box Co., Green Bay, Wis., replaced Mr. Cloud as secretary.

In the Process and Quality Control Committee, H. E. Dunholter, Owens Illinois Glass Co., Toledo, Ohio, succeeded H. W. Seibel, Gaylord Container Div., Crown Zellerbach Corp., St. Louis, Mo., as chairman; S. L. Goodrich, General Box Co., Des Plaines, Ill., replaced Mr. Dunholter as vice-chairman; and P. J. Cox, Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis., replaced Mr. Goodrich as secretary.

In the Production Committee, L. F. Ashwood, Downing Box Co., Milwaukee, Wis., succeeded Mr. Buttery as chairman, W. J. Hurrell, Hinde and Dauch Co., Ltd., Etobicoke, Ont., replaced D. Blackburn, formerly with Martin Paper Prod., Ltd., St. Boniface, Man., as vice-chairman; and F. Glass, Green Bay Box Co., Green Bay, Wis., replaced Mr. Ashwood as secretary.

In the Raw Materials Committee, A. L. Magnuson, Potlatch Forests, Inc., Lewiston, Idaho, replaced M. Block, Stone Container Corp., Chicago, Ill., as vice-chairman; and B. R. Gibson, Jr., St. Joe Paper Co., Port St. Joe, Fla., was appointed secretary.

Engineering Division. G. E. Shaad, General Electric Co.' Schenectady, N. Y., replaced V. P. Owens, Combustion Engineering, Inc., Windsor, Conn., as secretary.

In the Staff Advisory Committee, J. D. Lyall, Armstrong Cork Co., Lancaster, Pa., replaced E. H. Olmstead, Eaton-Dikeman Co., Mt. Holly Springs, Pa., as chairman.

In the Chemical Engineering Committee, John Lewis, Pulp and Paper Research Centre, Lawrence, Mass., was appointed vice-chairman.

In the Drying Committee, John Verweyen, Mead Corp., North Bergen, N. J., replaced S. G. Holt, Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis., as chairman; F. G. Perry, A. D. Little, Inc., Cambridge, Mass., replaced G. E. Jackson, Bowaters Carolina Corp., Catawba, S. C., as vice-chairman; and J. A. Villalobos, J. O. Ross Corp., New Brunswick, N. J., replaced K. K. Khandelwal, Beloit Iron Works, Beloit, Wis., as secretary.

In the Engineering Economics Committee, G. C. Davis, Bowaters Engineering and Development Corp., Calhoun, Tenn., was appointed vice-chairman; and J. Blood, Jr., St. Regis Paper Co., New York, N. Y., replaced F. C. Holmes, Bird Machine Co., La Porte, Ind., as secretary.

In the Fluid Mechanics Committee, P. E. Wrist, Mead Corp., Chillicothe, Ohio, replaced G. L. Calehuff, West Virginia Pulp and Paper Co., Covington, Va., as vice-chairman; and H. C. Nelson, Kimberly Clark Corp., Neenah, Wis., replaced J. A. Smith, Clark and Vicario Co., North Tarrytown, N. Y., as secretary.

In the Industrial Engineering and Materials Handling Committee, C. E. Green, B. L. Montague Co., Greenville, S. C., replaced H. A. Stoess, The Fuller Co., Catasauqua, Pa., as secretary.

In the Maintenance Committee, R. S. Welch, St. Regis Paper Co., Pensacola, Fla., was appointed vice-chairman.

In the Mechanical Engineering Committee, R. P. Finney, St. Regis Paper Co., E. Pepperell, Mass., was appointed vice-chairman.

In the Process Instrumentation Committee, E. W. Prince, Champion Paper and Fibre Co., Hamilton, Ohio, replaced J. K. Powell, Bowaters Southern Paper Co., Calhoun, Tenn., as chairman; G. G. M. Eastwood, Kimberly Clark Corp., Neenah, Wis., replaced Mr. Prince as vice-chairman.

In the Sanitary Engineering Committee, R. W. Simpson, Gilbert Associates, Reading, Pa., replaced F. J. Coogan, International Paper Co., Mobile, Ala., as vice-chairman; and A. E. Dembitz, Singmaster and Breyer, Inc., New York, N. Y., replaced L. L. Klinger, Whippany Paper Board Co., Whippany, N. J.

Pulp Manufacture Division. J. N. McGovern, Parsons and Whittemore, Inc., New York, N. Y., replaced M. B. Pineo, Scott Paper Co., Mobile, Ala., as chairman; and J. H. White, Keyes Fibre Co., Waterville, Me., was appointed vice-chairman.

In the Agricultural Fibers Committee, A. D. Meighen, Weston Paper & Mfg. Co., Terre Haute, Ind., replaced F. B. Grunwald, Consolidated Paper Co., Monroe, Mich., as chairman; T. F. Clark, U. W. Dept. of Agriculture, Peoria, Ill., replaced Mr. Meighen as vice-chairman; and G. C. Baron, Consolidated Paper Co., Monroe, Mich., replaced Mr. Clark as secretary.

In the Deinking Committee, A. J. Felton, Black Clawson Co., Middletown, Ohio, succeeded E. F. Andrews, International Paper Co., Niagara Falls, N. Y., as chairman; H. E. Corwin, Diamond National Corp., Palmer, Mass., replaced Mr. Felton as vice-chairman; and R. Kinne, Sealright-Oswego Falls Corp., Fulton, N. Y., replaced Mr. Corwin as secretary.

In the Pulp Purification Committee, R. J. Auchter, Kimberly Clark Corp., Neenah, Wis., succeeded F. Casciani, P. H. Glatfelter Co., Spring Grove, Pa., as vice-chairman; and L. B. Taylor, Columbia Southern Chemical Corp., Pittsburgh, Pa., replaced D. J. MacLaurin, Island Paper Mills, New Westminster, B. C., as secretary.

In the Mechanical Pulping Committee, S. R. Parsons, Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis., replaced J. K. Kirkpatrick, Bowaters Southern Paper Corp., Calhoun, Tenn., as chairman; T. F. Lahaise, Jr., Ryegate Paper Co., East Ryegate, Vt., succeeded Mr. Parsons as first vice-chairman; J. Blinka, Procter and Gamble, Cincinnati, Ohio, replaced M. Htoo, International Paper Co., Glens Falls, N. Y., as second vice-chairman.

The Acid Pulping Committee and the Semichemical Pulping Committee were combined into a new Sulfite Pulping Committee with P. E. Trout, Waldorf Paper Prod., Inc., St. Paul, Minn., chairman; P. J. Frost, Crown Zellerbach Corp., Camas, Wash., vice-chairman; and S. R. Parsons, Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis., secretary.

Testing Division. In the Routine Control Methods Committee L. J. Slentz, Allied Chemical Corp., Syracuse, N. Y., succeeded J. R. Gunning, Abitibi Power & Paper Co., Ltd., Georgetown, Ont., as committee chairman.

In the Adhesives Testing Committee R. C. Brown, U. S.

Envelope Co., Metuchen, N. J., succeeded W. Neuss, Armour Alliance Industries, Alliance, Ohio, as Committee Chairman.

In the Pulping and Papermaking Chemicals Testing Committee H. S. Hopkins, Olin Mathieson Chemical Corp., Baltimore, Md., succeeded T. S. Morse, Hercules Powder Co., Wilmington, Del., as committee chairman.

In the Wax Testing Committee R. W. Dannenbrink, Marathon Corp., Menasha, Wis., succeeded M. W. Kane, The KVP Co., Parchment, Mich., as committee chairman.

In the Paper and Paperboard Group W. C. Utschig, General Foods, Inc., White Plains, N. Y., succeeded W. H. Aiken, Personal Products Co., Milltown, N. J., as Group Chairman.

In the Paper Testing Committee W. P. Dohne, Dixie Cup Co., Easton, Pa., succeeded L. Price, U. S. Government Printing Office, Washington, D. C., as committee chairman.

In the Paperboard Testing Committee W. O. Kroeschell, Michigan Carton Co., Battle Creek, Mich., succeeded W. C. Utschig, General Foods, Inc., White Plains, N. Y., as committee chairman.

In the Paper Shipping Sack Testing Committee M. L. Taylor, Union Bag-Camp Paper Corp., New York, N. Y., succeeded K. A. Arnold, St. Regis Paper Co., New York, N. Y., as committee chairman.

In the Container Testing Committee A. W. Hoffman, Continental Can Co., New York, N. Y., succeeded M. J. Clark, Inland Container Corp., Indianapolis, Ind., as committee chairman.

A new Release Papers Testing Committee was formed under the chairmanship of P. S. Thomas, General Electric Co., Waterford, N. Y.

Research and Development Division. There were no chairmanship changes made in this division.

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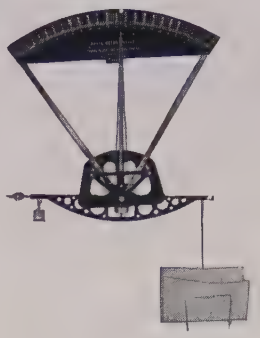

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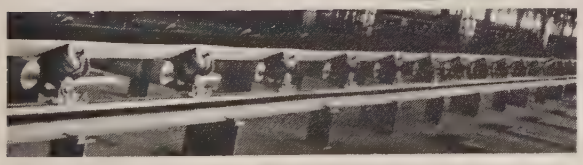

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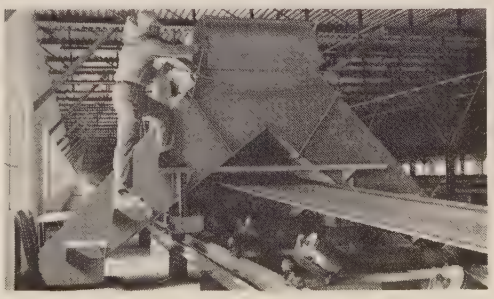

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PERSONAL MENTION

New TAPPI Members

Hasson I. Ahmed, Head of the Pilot Plant, Socete Generale de L'Industrie du Papier "RAKTA," Alexandria, Egypt, a 1953 graduate of Cairo University.

William M. Albrecht, Staff Chemist, International Business Machines Corp., Endicott, N. Y., a 1948 graduate of Lebanon Valley College.

John E. Baber, Sales, T. C. Heyward & Co., Jacksonville, Fla., a 1934 graduate of University of Virginia.

George S. Baker, Head, Research Library, The Bowater Research & Development Co., Ltd., Northfleet, Kent, England, a 1950 graduate of University College, London.

Pierre Barthelemy, Engineer, Batignolles-Chatillon Mecanique Generale, Paris, France. Attended Ecole Nationale d'Ingenieur des Arts & Metiers.

Joseph V. Bender, Sales Engineer, General Electric Co., Philadelphia, Pa., a 1952 graduate of Villanova University.

James O. Blackwell, Technical Assistant, Champion Paper and Fibre Co., Canton, N. C., a 1956 graduate of North Carolina State College.

Howard H. Blouch, Sales, Chromium Corp. of America, Chicago, Ill. Attended Case Institute of Technology.

Aldo P. Borsotti, Assistant Sales Manager, Beloit Papermachines, Pinerolo, Italy.

Thomas H. Boyd, Product Director, Industrial Sales Div., Refined Products Co., Lyndhurst, N. J., a 1948 graduate of Bowdoin College.

De Wane A. Brenner, Technical Service Engineer, Watervliet Paper Co., Watervliet, Mich., a 1957 graduate of Western Michigan University.

Robert E. Brouillard, Assistant to Vice-President, Penick & Ford Ltd., Inc., New York, N. Y., a 1938 graduate of Bates College with a Ph.D. degree in 1941 from Clark University.

August H. Brunner, Jr., Manager, Raw Material Quality Control Dept., Ansco, Binghamton, N. Y., a 1934 graduate of Fordham University.

Oliver N. Buhl, Research Director, Prime Leather Finishes Co., Milwaukee, Wis., a 1934 graduate of Marquette University.

Joseph H. Burges, Technical Consultant, Mead Pulp Sales Corp., Inc., New York, N. Y. Attended St. Therese College, Ireland.

Lewis A. Burnham, Engineer, Procter & Gamble, Cincinnati, Ohio, a 1955 graduate of University of Michigan.

Thomas W. Cadden, Product Development Engineer, West Virginia Pulp & Paper Co., North Charleston, S. C., and 1955 graduate of Georgia Institute of Technology.

Carl-Olov Carlsson, Sales Engineer, AB Karlstads Mekaniska Werkstad, Karlstad, Sweden, a 1955 graduate of Royal Institute of Technology, Stockholm.

Cecil N. Carter, Student, North Carolina State College, Raleigh, N. C.

Antonie Colijn, Manager, Meypro, N.V., Zaandam, Holland.

Robert U. Copland, Technical Sales Manager, L. & R. Organic Products Co., Inc., New York, N. Y., a 1933 graduate of Harvard College.

Roland A. Daigle, Mill Superintendent, Berkshire Tissue Mills, Inc., Hinsdale, Mass.

Douglas E. Davis, Technical Superintendent, Australian Paper Manufacturers, Ltd., Melbourne, Victoria, Australia, a 1925 graduate of London University.

John H. Dean, Technical Director, Colonial Board Co., Manchester, Conn., a 1959 graduate of N. Y. State College of Forestry.

Gaeton J. De Maessehalck, Chemical Engineer, Les Industrie. du Mais-Mainindustrie, Vilvoorde, Belgium.

Louis A. Di Corpo, Technical Sales Manager, Brookfield Engineering Labs., Inc., Stoughton, Mass., a 1957 graduate of Northeastern University.

Boyce W. Dougherty, Sales, Archer-Daniels-Midland Co., Minneapolis, Minn., a 1949 graduate of Kansas State University.

Urbain L. Doyle, Technical Specialist, Oxford Paper Co., Rumford, Me., a 1949 graduate of University of New Hampshire.

Maurie Edelstein, Personnel Director and Consultant, Dead River Co. and St. Croix Paper Co., Woodland, Me., a 1949 graduate of Boston University.

Morton Fefer, Market Development Chemist, Enjay Chemical Co., Elizabeth, N. J., a 1957 graduate of Northwestern University.

Wilbur E. Fisher, Jr., Chemical Engineer, Ketchikan Pulp Co., Ketchikan, Alaska, a 1956 graduate of Purdue University.

Ernesto F. Fuentes, Project Engineer, Parsons & Whittemore, Inc., New York, N. Y., a 1954 graduate of University of Florida.

Tsutomu Fukushima, Kokoku Rayon & Pulp Co., Ltd., Tokyo, Japan, a 1939 graduate of Institute of Technology, Kyoto.

Otto Gabbard, Technical Associate, The Beveridge Paper Co., Indianapolis, Ind.,

Merrit A. Gates, Customer Service Engineer, Owens-Illinois Glass Co., Toledo, Ohio, a 1924 graduate of University of Pennsylvania.

John J. Giambrone, Senior Chemist, Continental Can Co., Robert Gair Paper Products Group, Tonawanda, N. Y., a 1951 graduate of University of Buffalo.

Edward A. Gill, Research Chemist, Allied Colloids (Mfg.) Co., Ltd., Bradford, Yorks., England, a 1954 graduate of London University.

John W. Green, Chemist & Teacher, The Institute of Paper Chemistry, Appleton, Wis., a 1934 graduate of University of Pennsylvania with a Ph.D. degree from Princeton University in 1937.

Wilhelm Grunwald, Professor, Bibliothek der Technischen Hochschule, Hannover, Germany.

Gustave A. Harrer, Director of Libraries, Boston University Libraries, Boston, Mass.

Alfred J. Hart, Jr., Sales, E. I. du Pont de Nemours & Co., Inc., Cincinnati, Ohio, a 1943 graduate of Gettysburg College.

Gerald Hawkins, Special Assistant to Manager, Champion Paper & Fibre Co., Pasadena, Tex., a 1949 graduate of Louisiana State University.

Fritz O. Hedborg, Chief Engineer, Sandwell A. B., Stockholm, Sweden, a 1930 graduate of Kungl. Tekniska Hogskolan.

Gilbert L. Hembree, Sales Representative, Borden Chemical Co., Elmhurst, Ill., a 1949 graduate of College of Emporia.

Daniel S. Hoag, Process Engineer, Minneapolis-Honeywell Regulator Co., Pottstown, Pa., a 1948 graduate of Syracuse University.

Anthony B. Horlock, District Sales Manager, Hercules Powder Co., Ltd., London, England, a 1948 graduate of University of London.

Terence J. Hoverter, Librarian & Associate Professor, Moon Memorial Library, State University of N. Y. College of Forestry.

William C. Howard, Technical Assistant, Champion Paper & Fibre Co., Canton, N. C., a 1955 graduate of Clemson College.

Kimizo Izumi, Technical Section, Daima Cotton Spinning Co., Ltd., Osaka, Japan.

Lee T. Johnson, Salesman, Monsanto Chemical Co., St. Louis, Mo. Attended Northeastern University.

Leo S. Johnson, Technical Director, Cornell Paper Products Co., Div. of St. Regis Paper Co., Milwaukee, Wis.

Douglas R. Kanitz, Supervisor, General Purpose Control Section, EC&M Div., Square D Co., Cleveland, Ohio, a 1949 graduate of University of Wisconsin.

David K. Kennedy, Chemical Engineer, Allied Chemical Corp., Syracuse, N. Y., a 1958 graduate of Yale University.

Eugene R. Klos, Asst. Manager, Columbia Mill, Peter J. Schweitzer Div., Kimberly-Clark Corp., Lee, Mass., a 1943 graduate of Marquette University.

Roger J. Knobel, Plant Chemist, Keyes Fiber Co., Hammond, Ind., a 1949 graduate of Hamline University.

Gawain Koch, Production Manager, The Polymer Corp., Reading, Pa., a 1950 graduate of Goshen College.

Alfred F. Koller, Technical Translator & Abstractor, German Paper Trade Journal, The Chemical Abstracts Service, Biberach/Riss., West Germany.

Garnetta Kramer, Librarian and Assistant Attache, U. S. Information Service, Buenos Aires, Argentina, a 1938 graduate of University of Illinois.

Roland A. Labine, Jr., Assistant Edigor, McGraw-Hill Publishing Co., New York, N. Y., a 1957 graduate of Yale University.

Russell C. Lakey, Technical Service Representative, NOPCO Chemical Co., Newark, N. J., a 1952 graduate of Rhode Island School of Design.

James V. La Marre, Staff Chemist, Nalco Chemical Co., Chicago, Ill., a 1955 graduate of Michigan State University.

Andre H. Lemaitre, Manager, I.B.M. France, Vincennes, France, a 1928 graduate of Conservatoire National des Arts et Metiers.

Alexandria C. Maistros, In charge of Periodicals, Enoch Pratt Free Library, Baltimore, Md.

Helen J. Maunu, Head, Order Dept., Cleveland Public Library, Cleveland, Ohio.

Marshall Mazer, Vice President, Research & Development, Old Town Corp., Brooklyn, N. Y., a 1942 graduate of College of the City of New York.

Wesley G. Mitchell, Southern Representative, Beloit Iron Works, Beloit, Wis.

John S. Moran, Technical Assistant, S. D. Warren Co., Muskegon, Mich., a 1958 graduate of University of Notre Dame.

Sydney C. Murray, Jr., Sales Engineer, Durez Plastics Div., Hooker Chemical Co., North Tonawanda, N. Y., a 1944 graduate of St. Lawrence University.

Tadashi Nakada, Director & Mill Manager, Daishowa Paper Co., Ltd., Yoshinaga Mill, Shizuoka Pref., Japan., a 1925 graduate of Kiryu Technical College.

Oliver H. Newmarch, Chemical Engineer, MacMillan, Bloedel & Powell River, Ltd., Harmac, B.C., Canada., a 1938 graduate of University of British Columbia.

Osamu Niiro, Manager, Fiberboard Pilot Plant, Hokkaido Forest Products Research Institute, Hokkaido, Japan., a 1947 graduate of Muroran Technical College.

Willem A. Nikkel, Senior Project Engineer, West Virginia Pulp & Paper Co., Covington, Va.

Borje S. Niquist, Consulting Engineer, Kristinenhamn, Sweden.

Edward T. O'Brien, Chemist, P. H. Glatfelter Co., Spring Grove, Pa. Attended Pennsylvania State University.

Carlos D. Pereira, Jr., Technologist, Champion Cellulose S.A., Sao Paulo, Brazil, a 1957 graduate of University of Parana.

Robert C. Peterson, Research Chemist, Reyonier, Inc., Whippany, N. J., a 1960 graduate of N. Y. College of Forestry.

Wesley G. Price, Sales Representative, Wisconsin Wire Works, Appleton, Wis., a 1951 graduate of Boston University.

Fred M. Pugh, Sales Manager, Special Commodities Div., General Mills, Inc., Minneapolis, Minn., a 1947 graduate of Purdue University.

Robert Y. Rhyne, Sr., Chief, Pulp Laboratory, Olin Mathieson Chemical Corp., Pisgah Forest, N. C., a 1937 graduate of Lenoir-Ryne College.

Robert A. Robinson, Operating Superintendent, Celgar, Ltd. Castlegar, B. C., Canada, a 1948 graduate of Mt. Alliso., University.

Wilford H. Ross, Jr., Research & Development, Economics Laboratory, Inc., St. Paul, Minn., a 1950 graduate of Loyola University.

Gerald G. Row, Product Development, Ludlow Corp., Needham Heights, Mass., a 1941 graduate of Cornell University.

Rollin A. Schwinghamer, Control Superintendent, Abitibi Power & Paper Co., Sturgeon Falls, Ont., Canada, a 1941 graduate of University of Saskatchewan.

George E. Sewall, Chemical Engineer, Glidden Co., Baltimore, Md., a 1959 graduate of University of Maine.

Cephas B. Sitterson, Director, Research & Development, Appleton Woolen Mills, Appleton, Wis., a 1934 graduate of Wake Forest College.

William E. Skagerberg, Paper Specialist, General Mills, Inc., Minneapolis, Minn., a 1952 graduate of University of Minnesota.

Dorothea M. Sommer, Librarian, American Fore Loyalty Group, Continental Insurance Co., New York, N. Y.

Thomas C. Spence, Research Group Leader, The Dow Chemical Co., Williamsburg, Va., a 1942 graduate of Michigan State University.

Joe C. Sprague, Industrial Engineer, Green Bay Box Co., Green Bay, Wis. Attended Purdue University and Ball State College.

Paul W. Steffen, Engineer, Ingersoll Rand Co., New York, N. Y., a 1957 graduate of Stevens Institute of Technology.

George M. Suydam, General Superintendent, Case Bros.,, Inc., Manchester, Conn., a 1931 graduate of Lafayette College.

Elizabeth W. Tapia, Librarian, Eastman Kodak Co. Rochester, N. Y.

Cyril H. Tomalin, Head, Information Section, Paper & Board Divisional Lab., Albert E. Reed & Co., Ltd., Kent, England.

Carel M. Van Battum, Deputy, Netherlands Patent Office, The Hague, Holland, a 1948 graduate of University of Leiden.

Herbert S. Walter, Staff Engineer, Beloit Iron Works, Beloit, Wis., a 1948 graduate of Georgia Institute of Technology.

Richard H. Warrick, Junior Research Physicist, Weyerhaeuser Co., Longview, Wash., a 1960 graduate of Linfield College.

Quentin C. Weaver, Assistant Director for Administration, Scott Paper Co., Chester, Pa., a 1947 graduate of Gettysburg College.

Fred M. Wells, Associate Director, Procter & Gamble Co., Cincinnati, Ohio, a 1947 graduate of University of Kentucky.

Thomas W. Westlake, Technical Superintendent, Alliance Paper Mills, Ltd., Merritton, Ont., Canada., a 1936 graduate of University of Toronto.

Dennis A. Wiehe, Chemist, Blandin Paper Co., Grand Rapids, Minn., a 1959 graduate of University of Minnesota.

John E. Wilder, Mathematician, Oxford Paper Co., Rumford, Me., a 1956 graduate of University of Maine.

Robert J. Witters, Process Control Engineer, Scott Paper

Co., Chester, Pa., a 1954 graduate of Western Michigan College.

Bemis P. Wood, Vice-President, Production Strathmore Paper Co., West Springfield, Mass., a 1946 graduate of Northeastern University.

Rolf Zuber, Engineer, Herman ter Hell & Co., Hamburg, Germany.

Appointments

William H. Aiken, formerly of Personal Products Co., is now Director of Research and Development for Union Bag-Camp Paper Corp., New York, N. Y.

Ellis T. Anderson, formerly of Lone Star Bag & Bagging Co., is now a research and development engineer for Mira-Pak, Inc., Houston, Tex.

Walter A. Banks, of Black-Clawson Co., has been transferred from London, England to Middletown, Ohio.

Paul V. Barrow, formerly of Pen Mar Container Corp., is now Plant Manager of Downing Box Co., Milwaukee, Wis.

Raymond I. Bashford, Jr., of Penick & Ford, Ltd., has been transferred from New York, N. Y. to Cedar Rapids, Iowa.

Anders Bjorkman, formerly of Billeruds A/B, is now Professor of Industrial Chemistry at the Institute of Technology, Copenhagen, Denmark.

Mario Bonavia, formerly of Cartiere Burgo, is now with Cartiere Pigna, Bergamo, Italy.

Donald V. Brown, formerly of the Penobscot Chemical Fibre Co., has joined the staff of The Institute of Paper Chemistry, Appleton, Wis.

James G. Bullard, retired from Corn Products Sales Co., is a consultant at Bennington, Vt.

Elizabeth L. Case, formerly of G. D. Jenssen Co., is now a project engineer with Stadler, Hurter & Co., Montreal, Canada.

Claud B. Christiansen, formerly of the Diamond Alkali Co., is now Supervisor of Paper Research for Pittsburgh Plate Glass Co., Barberton, Ohio.

Charles H. Claypool, formerly of Oxford Miami Paper Co., is now Mill Manager for Nova Scotia Pulp, Ltd., Port Hawkesbury, N. S., Canada.

Orman P. Curtis, formerly of the West Virginia Pulp & Paper Co., is now a project engineer for Beloit Eastern Corp., Downingtown, Pa.

Eugene de Luca, formerly of Electric Reduction Co. of Canada, is now with Celgar Ltd., Castlegar, B. C., Canada.

E. Paul Duncan, formerly of Hooker Chemical Co., is now a sales representative for Weyerhaeuser Co., Tacoma, Wash.

Arthur G. Eltzroth, of Container Corp. of America, has been transferred from Fernandina Beach, Fla. to Baltimore, Md. as Plant Superintendent.

Robert C. Fuehrer, formerly a student at the University of Maine, is now a process engineer for Spaulding Fibre Co., Milton, N. H.

John P. Greiveldinger is now Eastern District General Manager of the Corrugated Container Division of Continental Can Co., Teterboro, N. J.

Donald D. Hall, formerly of Eastern Fine Paper and Pulp Division of Standard Packaging Corp., is now a staff engineer for the Howard Smith Paper Mills, Ltd., Cornwall, Ont.

John A. Hartsock, formerly of International Paper Co., is now a development engineer for Olin Mathieson Chemical Corp., Packaging Division, New York, N. Y.

Fred A. Haselow, formerly of Charmin Paper Products Co., is now with Mosinee Paper Mills, Mosinee, Wis.

Robert Herdman, of Bowaters Engineering & Development, Inc., has been transferred from Corner Brook, Newfoundland to Calhoun, Tenn.

Warren E. Hesler, formerly of Swenson Evaporator Co., is now Eastern Regional Sales Manager for Buflovak Equipment Division of Blaw-Knox Co., New York, N. Y.

Robert E. Ingison, formerly of Brownville Board Co., is now Technical Director of the Dilts Division of Black-Clawson Co., Fulton, N. Y.

Charles D. Ingram, of Scott Paper Co., has been transferred from Mobile, Ala. to Chester, Pa. as Research Chemist.

Lawrence M. Joseph, formerly of Gremayel Freres, Beirut, Lebanon, is now Mill Manager of United Paper Products Corp., Windsor Locks, Conn.

Raymond J. Lodge is now Vice-President of the Adhesives & Chemicals Division of the Borden Chemical Co., New York, N. Y.

Bernard Majani, formerly of Black-Clawson Co., is now a sales engineer for Hale & Kullgren, Inc., Akron, Ohio.

James W. Maxwell, formerly of Gulf States Paper Co., is now Coating Supervisor for Riegel Paper Corp., Acme, N. C.

Thomas J. Neel, formerly of Keever Starch Co., is now with The Hubinger Co., Keokuk, Iowa.

R. C. Ratliff, formerly of the Gaylord Container Division, has been transferred from Bogalusa, La. to Camas, Wash. as Manager of Paper Products Development in the Central Research Division of Crown Zellerbach Corp.

Genevieve L. Reidy, formerly of St. Regis Paper Co., is now Technical Librarian for Deering Milliken Research Group, Spartanburg, S. C.

Nicolas M. Reitzel, formerly of West Virginia Pulp & Paper Co., is now a development engineer for Rice Barton Corp., Worcester, Mass.

John H. Rich, formerly of Riegel Paper Co., is now General Manager of Garden State Paper Co., Garfield, N. J.

James O. Starkweather, formerly of Ebasco Services, Inc., is now a project manager for M. W. Kellogg Co., New York, N. Y.

Robert M. Sternberger, formerly of Hearst Enterprises, Inc., is now Mill Manager of Southwest Forest Industries, Inc., Snowflake, Arizona.

Larry L. Thompson, formerly of Frank C. Vaughan Engineers, is now with IBM Research Center, Yorktown Heights, N. Y.

De Forrest V. Wade, formerly of St. Regis Paper Co., is now Chief Engineer for Southern Associated Engineers, Inc., Orlando, Fla.

Thomas E. Yockey, formerly of Magnavox Co., is now with Orchard Paper Co., St. Louis, Mo.

* * *

W. F. Taylor is now the corporate representative of Ecusta Paper Division of Olin Mathieson Chemical Corp., Pisgah Forest, N. C. in the Technical Association.

R. T. Lawless has succeeded *M. J. Lawless* as the corporate representative of Lawless Brothers Paper Mills, East Rochester, N. Y.

W. G. Bretson has succeeded *C. L. Kraning* as the corporate representative of Minnesota Mining & Mfg. Co., St. Paul, Minn. in TAPPI.

* * *

J. E. Davis has succeeded *T. S. De Woody* as the official representative of Diamond Alkali Co., Cleveland, Ohio in TAPPI.

The name of the Electric Steel Foundry Co., Portland, Ore. has been changed to ESCO Corp.

G. Girdwood has succeeded *W. F. Pitkin* as the official representative of Dorr-Oliver, Inc., Stamford, Conn. in the Technical Association.

Michael T. Tormey has succeeded *D. E. Milne* as the official representative of Anglo-American Clays Corp., New York, N. Y. in TAPPI.

INDUSTRY NOTES

North American

Statistics

*Paper and Paperboard: 1960**

Total output of the paper and allied products industry moved to a new high in 1960, edging 1% above the 1959 total. Output by primary producers also reached a new high at an estimated 34.3 million tons. Among the major sectors of industry, paper production at 15.3 millions tons and paperboard production at 15.7 million tons were each above their previous highs established in 1959. Output of construction paper and board, at 3.2 million tons, was down from 1959's record high of 3.4 million tons, as a result of the weakness in residential housing construction.

Part of the increase in total paper and board production resulted from a gain in paper and paperboard exports. Imports of paper and board, however, estimated at 5.6 million tons, remained the same as the 1959 total. Apparent consumption of paper and paperboard (production plus imports less exports) thus also moved to a new high of 39.0 million tons, up about 1% from 1959's 38.7 million tons. This increase was less than that of the total population, and per capita consumption of paper and paperboard moved down from 1959's 437 lb. to an average level of 432 lb. Note, however, that per capita consumption of paper and paperboard excluding construction paper and board showed a somewhat more steady pattern, with 1960's per capita consumption as 396 lb. compared to 1959's 398 lb. per capita.

Inventories Reduced. For the most part, activity in the paper industry in 1960 failed to keep pace with activities in its end use markets, or in the economy as a whole. Total output of goods and services, as measured by the gross national product in terms of constant dollars, rose by about 2.8% from 1959 to 1960; final purchases of goods and services rose by 3%. This compares to the 1% gain in output of the paper and allied products industry. The relatively slower pattern of activity in the paper and allied products industry can be fairly well explained by the movement of inventories of these products in the channels of distribution. In 1959, paper production was pretty well in line with final consumption, while paperboard production was actually a little above the rate of final paperboard consumption. In 1960 output of both paper and paperboard were each a little below the rate of consumption, and part of the nation's requirements for these products were drawn from inventories. This was in keeping with the general relationship between production of materials and production of finished goods for the economy as a whole. Federal Reserve Board production indexes show, for example, that output of finished goods was consistently above output of raw materials throughout 1960; paper and paperboard may well be classified as industrial raw materials. On this basis, it is reasonable to expect increases in output of paper and paperboard as soon as inventories of these products in the channels of distribution cease being depleted. Such a gain would be necessary merely to bring output back to rate of final consumption. Should the economy shake off the effects of the present adjustment in the last half of 1961, as is generally expected, and again move upward, total output in the paper and paperboard industry would also be expected to follow a comparable trend.

Paper and Paperboard Markets. The total market for paper may be broken down into three major sectors: (1) the printing and publishing industries; (2) those industries that use paper for packaging or industrial uses; and (3) consumers, who buy many different types of paper for home use. A major support for paper demand in 1960 was the strength in activity in the printing and publishing industries. The Federal Reserve Board index of output of newspapers, magazines, and books made a new high of 114 (1957 = 100) in 1960, up 7% from the 1959 level. Total printing and publishing activity increased by 6% from 1959 to 1960. These gains were among the largest recorded among the major manufacturing industries, and output of printing papers also showed the strongest increases among the various paper grades.

The market for paper packaging materials and paper for industrial uses may be measured by output of nondurable goods. Production of all nondurable goods in 1960 averaged out about 2% above the 1959 total. Consistent with that pattern, total production of coarse papers and of special industrial papers showed only moderate gains from 1959 to 1960.

Consumer requirements for paper products may be measured by trends in consumer income after taxes, adjusted for price changes. On this basis, consumer income in 1960 was some 3% over the 1959 total. Output of sanitary tissue stock which includes such consumer products as paper towels, napkins, facial tissue, and toilet tissue, showed about a 6% gain from 1959 to 1960.

Paperboard is used primarily as a packaging material. The APPA index of paperboard requirements, which is based upon indexes of output in paperboard's major markets weighted according to their relative importance to the paperboard industry, showed about a 4% gain from 1959 to 1960. Paperboard production, as noted above, showed a gain of only 1%. The difference can probably be ascribed to a reduction of inventories of paperboard and paperboard products in the channels of distribution. Thus, some strength in paperboard production may be expected when inventory reduction ceases. Aside from these inventory movements, the paperboard industry is closely geared into the activity of the economy as a whole.

Raw Materials. The record-breaking activity in the paper and paperboard industry in 1960 was accompanied by new highs in wood pulp production and consumption. Total pulp production in 1960 is estimated to have exceeded 25 million tons, a gain of about 3% from the 1959 total. Part of this gain stemmed from a tremendous increase in exports: wood pulp exports, which totaled about 700,000 tons in 1959, moved up to about 1.1 million tons in 1960. Total new supply of wood pulp (production plus imports less exports) was 26.5 million tons, about 1% above the 1959 total.

Labor. Despite the gain in total output of pulp, paper, and paperboard, there was no increase in the number of production workers from 1959 to 1960. Similarly, there was virtually no change in the number of production workers for the entire paper and allied products industry. However, total employment in both the paper and allied products industry as a whole and the pulp, paper, and board sector rose by about 1% from 1959 to 1960. This is consistent with the pattern evident throughout the entire postwar period, in which the number of white collar workers has expanded, while the number of production workers has shown little change.

* American Paper and Pulp Association, *Monthly Statistical Summary*, 39, No. 1 (January, 1961).

Output per production-worker man-hour in pulp, paper, and board mills rose by roughly 3% between 1959 and 1960.

Sales and Earnings. The dollar value of sales in the paper and allied products industry in 1960 showed a very moderate gain over the 1959 total. Prices of paper averaged out to within 1% of the 1959 level, while paperboard prices showed a small decrease. Profits of corporations in the paper and allied products industry appeared to have been about 5% below the 1959 rate, reflecting, in part, a 4% gain in average hourly earnings of production workers, a 6% increase in depreciation charges, and the relative stability in paper and paperboard prices during most of 1960.

If the nation's economists are correct in their prediction of an early end to the present downward movement of the total economy, and a generally rising pattern of economic activity during the last half of 1961, the accompanying increase in paper and paperboard output will be paralleled by a corresponding increase in sales, and a healthier price and profit structure than prevailed in the last half of 1960.

*Pulpwood**

Total receipts of pulpwood for January–October were 34,671,000 cords, an increase of 3,086,000 cords over receipts for the comparable period last year. Domestic receipts were 2,999,000 cords above the year earlier total, and imports increased 87,000 cords. All of the regions showed increases ranging from 3% in South Central to 16% in the North Central region.

Pulpwood consumption for January–October, 1960, was 34,066,000 cords, an increase of 1,588,000 cords over the same period of 1959. All of the regions showed increases ranging from 1% in South Central to 8% in the North Central region.

Inventories of pulpwood at the end of October were 5,937,000 cords, an increase of 178,000 cords above September, 1960, and a 1,012,000 cords increase above October, 1959. All the other regions showed increases ranging from 10% in North Central to 108% in the South Atlantic region.

*Waste Paper and Other Fibrous Materials**

October waste paper receipts were 776,000 tons; for the first ten months of this year they totaled 7,498,000 tons, a decrease of 326,000 tons below receipts for last year.

Waste paper consumption for October was 770,000 tons; the January–October total was 7,541,000 tons, a decrease of 168,000 tons from consumption for the same period last year.

Inventories at the end of October were 544,000 tons, 6000 tons above September and a decrease of 6000 tons below inventories at the end of October, 1959.

Consumption of total fibrous materials for October was 849,000 tons; the January–October total was 8,367,000 tons, 218,000 tons below consumption for the comparable period last year.

Inventories of total fibrous materials at the end of October were 882,000 tons, 2000 tons below September and 27,000 tons below inventories at the end of October, 1959.

*Wood Pulp**

Production of wood pulp for January–October, 1960, was 21,134,000 tons, an increase of 857,000 tons above the comparable 1959 total.

Wood pulp consumption in the manufacture of paper and board for January–October, 1960, was 21,549,000 tons, an increase of 550,000 tons above consumption for the same period last year.

Imports of wood pulp for January-October, 1960, were 1,980,001 tons, 1% below imports for last year. Imports from Canada for January–October, 1960, were 1,695,126 tons, 4% above the comparable period of 1959. Overseas imports for January–October, 1960, were 284,875 tons as compared to 368,860 tons for the same period last year.

Exports of wood pulp for January–October, 1960, were 948,869 tons, as against 526,509 tons exported during the same period last year

Inventories of wood pulp at paper and board mills at the end of October were 545,887 tons, 7659 tons above inventories at the end of September and 23,228 tons above inventories at the end of October, 1959.

Survey of Capacity—Paper and Paperboard, 1959–1963 (1000 Short Tons)

	1959	*1960*	*1961*	*1962*	*1963*
Total Paper and Board	37,504	38,847	40,488	41,651	42,127
Total Paper	15,619	16,189	16,803	17,314	17,485
Newsprint	2,416	2,293	2,306	2,353	2,371
Uncoated groundwood	844	901	848	912	966
Uncoated book	1,723	1,874	1,909	1,935	1,939
Coated	2,024	2,099	2,251	2,351	2,385
Fine	1,784	1,888	2,105	2,154	2,170
Coarse	3,869	3,999	4,090	4,255	4,275
Spec. indus. & absorbent	750	846	903	915	919
Tissue	2,209	2,289	2,391	2,439	2,460
Total Paperboard	17,447	18,182	19,184	19,813	20,108
Containerboard	9,401	9,819	10,515	11,013	11,128
Boxboard	5,586	5,873	6,097	6,180	6,361
All other	2,460	2,490	2,572	2,620	2,619
Total bldg. paper & board & wet machine board	4,438	4,476	4,501	4,524	4,534
Building papers	1,582	1,556	1,550	1,550	1,559
Building board	2,669	2,727	2,741	2,755	2,755
Wet machine board	187	193	210	219	220

Note: Paper capacity based on 310-day year; paperboard on 313-day year.

Source: Joint American Paper and Pulp Association—National Paperboard Association Capacity Study—1959–1963, issued December, 1960.

Folding Carton Industry—Outlook for 1961 and Review of 1960

Based on first-9-month data, 1960 output of folding boxboard rose 2.9% and value of shipments 0.1%, and shipments of folding cartons declined 1.9%, compared with 1959 levels, the Business and Defense Services Administration, U. S. Department of Commerce, reported. Continued growth of the folding carton industry in 1961 appears to depend upon the maintenance of the current volume of business, supplemented by innovations incorporating the physical properties of film and foils. Shipments of folding cartons in 1961 are expected to approximate those in 1960, according to industry sources.

Background

The folding carton, a nondurable goods packaging container, plays an important role in modern retailing. Bulk packaging of commodities requiring repackaging to reach the consumer level has contributed little in the way of sanitation, food preservation, or convenience. In contrast with the open containers of past years are today's folding cartons containing individual servings. This new-type package uses materials whose physical properties contribute to retention of the product's original quality.

Although designed specifically for a given product, the folding carton has been found to be adaptable for many purposes. Its attributes include rapid production of the container, automatic speed packaging of the product, display qualities necessary for impulse buying of retail merchandise, and consumer acceptance with respect to quantity and convenience.

The folding carton field is highly competitive, as indicated by the steady decline in net profit and return on investment over the years. Material and labor costs have outpaced price increases of the finished product. From 1947 to 1959, net profit has dropped from a rate of 7.7 to

2.0%, and returns on investment from 21.8 to 8.8%, while production increased by approximately 100%. Better management and manufacturing practices have been adopted by many manufacturers to effect economies. Though serious efforts have been made to retain current markets and develop new uses for folding cartons, apparently increased production volume as a remedy for the industry's difficulties has been overemphasized. In other words, increased production may not provide increased profits.

Trends in 1960

While folding boxboard production was up 2.9% and value 0.1% in January–September, 1960, over 1959, tonnage shipped declined 1.9%. New orders for folding cartons in 1960 did not reach 1959 levels. End-use trends showed declines in beverages, sporting and rubber goods, toys, medicinals, and tobacco, and the rate for other groups did not maintain growth levels throughout the year. The following 1957–60 data of the Folding Paper Box Association of America and the Bureau of the Census on folding paper box production and shipments reflects the growth of the industry:

Year and quarter	Shipments of folding paper box (million dollars) Quarterly	Annually[a]
1957:		
First	251	904
Second	230	920
Third	230	920
Fourth	233	931
1958:		
First	223	894
Second	221	884
Third	231	924
Fourth	231	925
1959:		
First	229	916
Second	235	942
Third	240	962
Fourth	237	947
1960:		
First	237	947
Second	237	947
Third	231	924
Fourth	232 (est.)	928

[a] Seasonally adjusted quarterly totals at annual rates.

Year	Production of folding boxboard, excluding special foodboard (thousands of short tons)
1950	2376
1951	2384
1952	2233
1953	2509
1954	2502
1955	2691
1956	2739
1957	2786
1958	2833
1959	2928
1960 (est.)	2975

The 1961 Outlook

A narrowing margin between costs of manufacture and sales returns has resulted in increased production to attain increased sales volume. To maintain present markets, the industry must develop new uses by the utilization of materials such as films, foils, and rigid plastics, and must improve cartons now in use. The outlook for 1961 and the future of the folding carton industry will be commensurate with the effort devoted to the improvement of the products and the development and adaptation of packaging for new fields of use. Shipments of folding cartons in 1961 are expected by the industry to approximate 1960 levels.

Shipments

Shipments of folding cartons in 1960 totaled $941 million, according to the Folding Paper Box Association of America. The volume was 0.3%, or $3.1 million short of the all time high set in 1959. The 2,315,500 tons of boxes shipped during the year were 2.2%, or 41,800 tons less than the 1959 total.

Corn Industries Research Foundation

Research in corn and its components, principally starch, will occupy 25 scientists working on grants from Corn Industries Research Foundation, Inc., during 1961. Trustees of the Foundation, at their recent annual meeting in New York, approved the continuance of existing research studies and authorized several new investigations, in a program totaling more than a quarter of a million dollars for the year. Frank K. Greenwall, president of the Foundation and chairman of the Board of National Starch and Chemical Corporation, New York, announced the grants-in-aid to 18 universities and other institutions.

Now in its 27th year, the Foundation's basic-research program is administered by a committee of scientists from the corn-refining companies which compose the foundation. This industry-wide program supplements the individual research of these companies.

National Bureau of Standards

Research Highlights, a new publication of the National Bureau of Standards, presents in compact, digest form an illustrated account of National Bureau of Standards research and measurement activities in fiscal year 1960. The Bureau's vigorous research program is portrayed, reflecting this agency's role of leadership in the science of measurement and its concentrated effort to meet the dynamic measurement requirements of American science and industry. Additional features of *Research Highlights* include a complete list of NBS publications and patents for fiscal 1960; a description of the calibration, testing, and standard sample services to science, industry, and government; a résumé of the Bureau's cooperative research programs with industry and of its cooperation with Federal, State, and local governments, professional societies and standardizing bodies, and many international groups to solve problems relating to measurement standards and techniques.

Research Highlights of the National Bureau of Standards, Annual Report 1960, National Bureau of Standards Miscellaneous Publication 237, 189 pages, 65 cents. (Order from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.).

Process Equipment Manufacturers Association

The formation of the Process Equipment Manufacturers Association was announced following the first annual meeting held on January 12 at the Harvard Club, New York. One of its principal purposes is to assist its member companies in improving the efficiency of their operations and thereby rendering increased services to their customers.

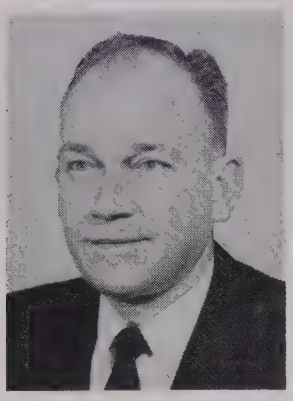
J. D. Hitch, Jr., director of Dorr-Oliver, Inc., is president, and Harlowe Hardinge, president of Hardinge Co., is vice-president. R. P. Kite, executive secretary-treasurer, is located at 551 Fifth Ave., Room 1412, New York 17, N. Y.

Paper Manufacturers and Converters

Bowaters Carolina Corp.

Richard L. Betts has been named paper mill manager for Bowaters Carolina Corp. Mr. Betts joins Bowaters with over 20 years of pulp and paper industry experience. At Champion Paper and Fiber Co. for 23 years, he served as general paper mill superintendent and production manager for the Texas Div. at Pasadena, Tex. He most recently held several positions in Champion's general offices located in Hamilton, Ohio.

Jack E. Chinn has been named assistant paper mill manager.



J. K. Dyer,
Bowaters Southern Paper Corp.

W. J. Parson,
Bowaters Southern Paper Corp.

Mr. Chinn was formally employed as technical superintendent by Consolidated Water Power and Paper Co. at Wisconsin Rapids, Wis.

Bowaters Southern Paper Corp.

At Bowaters Southern Paper Corp., Calhoun, Tenn., John K. Dyer has been named production manager—pulp, and Walter J. Parson, production manager—newsprint, according to L. E. Culbertson, Bowaters Southern mill manager.

Chillicothe Paper Co.

Richard H. Green has been appointed technical director of the Chillicothe Paper Co. effective January 30, it was announced by N. A. Seidensticker, president of The Mead Corp. subsidiary.

Consolidated Water Power & Paper Co.

Technical supervision at the Wisconsin River Div. of Consolidated Water Power & Paper Co. is being enlarged in line with the current expansion program now in progress there. The expansion program includes a new enamel paper machine and auxiliary facilities. Joseph Streb has been named technical supervisor, paper, and William Anderson has been appointed technical supervisor, pulp.

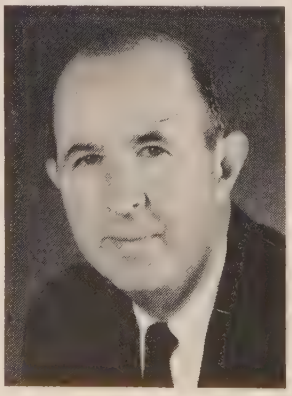
Also, John Kruger, quality control engineer in the division's Technical Dept. has been appointed assistant superintendent of the Coating Dept. and William G. Stake has neen named clerical supervisor in the Maintenance Dept.

Continental Can Co.

Peter P. Wojtul, a vice-president of Continental Can Co. and formerly general manager of the Fibre Drum & Corrugated Box Div., has been named general manager of the boxboard, folding carton, and fiber drum operations of the company, according to Charles B. Stauffacher, executive vice-president of the Robert Gair Paper Products Group.

Mr. Stauffacher also announced the appointment of Lewis B. Pitts, formerly Northeast area manager of the Fibre Drum & Corrugated Box Div., as general manager of the newly created Corrugated Container Div.

J. P. Greiveldinger, formerly manager of manufacturing engineering at Continental Can's Fibre Drum and Corrugated Box Div., has become Eastern District general manager of the firm's newly formed Corrugated Container Div., according to L. B. Pitts, Division general manager.



P. P. Wojtul,
Continental Can Co.

N. A. Pease, previously assistant to the manager of manufacturing engineering at the old Fibre Drum and Corrugated Box Div., is now manager of manufacturing engineering for the new division.

Three other personnel appointments in the Corrugated Container Div. of Continental Can Co. have been announced. J. R. Bevers has assumed the responsibility of sales manager for corrugated displays, with headquarters in New York City. F. E. Goodrich has become sales manager for new products development and will be located in Chicago. C. H. Root is now director of corrugated box research and development in Van Wert, Ohio.

Crossett Co.

Crosset Paper Mills is nearing completion of a $1,770,000 improvement project on its lightweight kraft paper machine. This includes the installing of a new headbox, new breaker stack, four air driers, and converting the machine's size press to a new type.

The program is designed to improve the quality of kraft paper from this machine and expand production volume by 15 tons per day. The changes will also make possible the manufacture of some new grades of lightweight kraft paper.

Crown Zellerbach Corp.

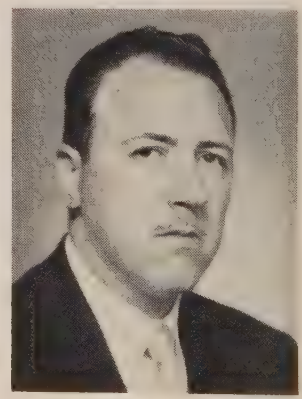
Crown Zellerbach Corp.'s Central Research Div. announced promotions of two staff members at the Camas-based research center. Dr. J. S. Barton, director of research, said F. C. Ratliff, formerly technical director at Crown Zellerbach's Bogalusa, La. Division, has been named manager for paper products development at the Camas installation, and J. G. Coma has been advanced from associate engineer at the Chemical Products Div. to supervisor, chemical process research, in the Central Research Div.

N. J. Lasater and D. R. Blow have joined the staff of Crown Zellerbach's Central Research Division. Lasater has assumed duties as an assistant chemist in the paper products service section. Blow is serving as an associate engineer with the division's paper specialties development section.

Downing Box Co.

Paul V. Barrow has joined the Downing Box Co. to become the plant manager of the new plant soon to be constructed in Minneapolis. Mr. Barrow has been in the container industry for the past 25 years and was formerly associated with Container Corp. of America and Inland Container Corp.

L. B. Pitts,
Continental Can Co.



J. P. Greiveldinger,
Continental Can Co.

W. R. Grace & Co.

International Paper Company and W. R. Grace & Co. have announced the signing of an agreement under which International Paper Company has acquired the Grace paper enterprises in Puerto Rico and Mexico and will participate with Grace in an operation in Columbia.

International Paper's acquisition consists of the Grace pulp and paper mill in Puerto Rico and the paper converting plants in Puerto Rico and Mexico. International Paper also will participate equally with Grace in the ownership of a pulp and paper mill now nearing completion at Cali, Colombia.

The Grace paper manufacturing and converting operations in Peru are not involved in the transaction.

International Paper Co.

S. E. Kay Safety Award

International Paper Company's Niagara Falls mill has been awarded the company's S. E. Kay Safety Award for the year 1960, it was announced today by R. C. Masterman, manager of International Paper's Northern Div. The award is made annually to whichever of the company's six mills in the northeastern United States shows the greatest percentage improvement over the previous three-year average in its mill injury frequency rate. The Niagara Falls mill showed a 61% improvement in 1960.

Staff

William G. Loeffler, Jr. has been appointed manager of the A. M. Collins plant of International Paper Co. in Philadelphia, Pa. The A. M. Collins plant manufactures specialty coated papers and has been well known for over 100 years for its quality coated cover papers and fancy embossing.

Olin Mathieson Chemical Corp.

Leon H. Garfield has been appointed production manager for the carton operations of the Packaging Div. of Olin Mathieson Chemical Corp. Mr. Garfield has been active for the past fourteen years in carton production management activities. He has had extensive experience in the three major types of carton printing: lithography, letterpress, and rotogravure. All three of these printing processes are available from Olin.

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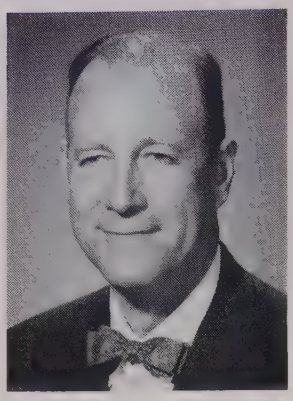
WYANDOTTE CHEMICALS

MICHIGAN ALKALI DIVISION, WYANDOTTE, MICHIGAN

Nova Scotia Pulp, Ltd.

Charles H. Claypool has been appointed mill manager of Nova Scotia Pulp, Ltd., at Port Hawkesbury, Cape Breton Island, N. S., Canada, effective January 1, 1961. Nova Scotia Pulp is a joint subsidiary of Stora Kopparbergs Bergslags A/B of Sweden and Scott Paper Co. The mill is now under construction and is scheduled for start-up during the first quarter of 1962.



C. H. Claypool, Nova Scotia Pulp, Ltd.

St. Regis Paper Co.

Roy K. Ferguson Safety Award

This year's presentation of St. Regis Paper Co.'s Roy K. Ferguson Safety Award was made Monday, January 30, at the company's headquarters' offices in New York. Named in honor of St. Regis' Chairman of the Board, the award is presented annually to the St. Regis location with the best three-year cumulative safety record.

Presentation this year was made to St. Regis Container Division's Mt. Wolf, Pa., plant. Mt. Wolf had a frequency rate of zero in lost time injuries over the past 3 years, and during this period accumulated a million man-hours without a lost time injury.

Union Bag-Camp Paper Corp.

Union Bag-Camp Paper Corporation announced that William H. Aiken joined the company on Feb. 15, 1961, as director of research and development. Prior to joining the Union-Camp organization, Dr. Aiken directed research and development for Gardner Board and Carton Co. and its successor, the Diamond Gardner Corp. Most recently he served both as a director and vice-president, research and development engineering, of Personal Products Corp., one of the Johnson & Johnson companies.

Weyerhaeuser Co.

Hamilton Paper Co. Merger

Hamilton Paper Company, an important producer of bond, offset, text, and reproduction papers, has announced that agreement has been reached with Weyerhaeuser Co. for the merger of Hamilton with Weyerhaeuser. Hamilton mills are located at Miquon, Pa., and Plainwell, Mich.

Staff

The reorganization of the Longview pulp and paperboard branch of Weyerhaeuser Co. has been announced by Russel J. LeRoux, manager of manufacturing, pulp and paperboard division.

The major changes as announced by Edgmont N. Wennberg, manager of the Longview pulp and paperboard branch, are: J. R. Callahan, Jr., who has been serving as assistant branch manager at Longview, will become production manager-board, and will continue to act for the branch manager in his absence.

Andrew A. Broz, who has held the post of technical director of the Everett sulphite mill, will become production manager-pulp at the Longview branch.

Three other assignments were announced by Mr. LeRoux. Robert H. Quick, assistant technical director-paperboard, at Longview, will become technical coordinator-board; Glenn E. McAfee, Longview mill sales representative, becomes coordinator of sales of pulp and board with the additional responsibility for export shipments; and Glen W. Potter, pulpwood buyer at Longview, will be coordinator of wood source and supply.

Educational Institutions

Maine

Second Pulp and Paper Institute

Combining the classroom lecture with the experience of the manufacturing processes is a feature of the second Pulp and Paper Institute to be held July 10–August 17 at the University of Maine. Executives of 16 pulp and paper and allied companies are to be lecturers at this event which is sponsored by the University of Maine Pulp and Paper Foundation in cooperation with the University of Maine.

Professor Lyle C. Jenness, head of the Chemical Engineering Department of the University of Maine and director of the Institute, announced the following lecturers, each of whom is an expert in his field. John C. W. Evans, editor of the *Paper Trade Journal;* N. P. Carthage, secretary-treasurer, Carthage Machine Co.; W. David Kerr, Fraser Paper Company Ltd.; Robert W. Doe, superintendent, West Virginia Pulp & Paper Company; Frederick G. Perry, and head Process Development Department, A. D. Little Co.; Edward M. Root, sales manager, Black-Clawson Company.

Lecturers for the Paper Technology course are Joseph H. Robertson, chemist, Howard Smith Paper Mills; Dwight E. Jones, executive vice-president, E. D. Jones Co.; James J. Harrison, vice-president for manufacturing, New Haven Box and Carton Co.; Glenn T. Renegar, mill manager, Container Corp.; Lester J. Tarbell, assistant to vice-president, Bird & Son, Inc.; F. O. Sundstrom, technical service, American Cyanamid Co.; Monro L. Boinest, paper mill superintendent, Halifax Paper Co.; David F. Pollard, production manager, Great Northern Paper Co.; Robert Bancroft, Eastern Division, Standard Packaging Corp.; William E. Anderson, Jr., assistant superintendent, Converting Dept., Riegel Paper Corp.; H. M. Gray, vice-president operations, Sealright Oswego Falls Corp.; and D. D. Uong, senior vice-president, Fitchburg Paper Co.

In addition to the above lecturers, Professor Jenness has arranged for visiting staff members from six other institutions which teach pulp and paper technology.

The first 3-week course devoted to pulp technology will open July 10. The paper technology course will open July 31 and conclude August 17.

Committee members assisting Professor Jenness in making plans for this institute are Frederic A. Soderberg, vice-president, Huyck Corp., chairman; William H. Caddoo, vice-president, Continental Can Company; Harold M. Annis, vice-president Research and Development, Oxford Paper Co.; W. A. Ketchen, vice-president, Fraser Paper, Ltd.; J. H. Heuer, vice-president Manufacturing, Great Northern Paper Co.; Thomas G. Mangan, retired manager, International Paper Co.; and George H. Rand, manager Manufacturing, International Paper Co., Northern Mills.

Miami University

Miami University students of pulp and paper chemistry and techniques will continue to hear talks on special phases of the industry by visiting experts in the coming semester, according to C. Edwin Brandon, director of the Miami pulp and paper program.

First speaker of the second semester will be a Miami graduate, Harold M. Annis, vice-president of Oxford Paper Co. and national president of the Technical Association of the Pulp & Paper Industry (TAPPI). Others through the semester will include Richard Hunter, Silver Springs, Md., president of Hunter Associates Laboratories and chairman

of the TAPPI Optical Methods Committee, and Kenneth P. Geohegan, Dayton, vice-president of Howard Paper Mills, Inc., and former national president of TAPPI.

Most recent speaker has been James P. Casey, of Union Starch Co., Columbus, Ind., whose book "Pulp and Paper" is a standard work in the field. Others have included C. O. Donofrio, director of new processes and products for Champion Paper & Fibre Co.; Robert B. Hobbs, chief of the paper section of the National Bureau of Standards, Washington, D. C.; William Beckett, president of Beckett Paper Co., Charles Lee, of the Formex Corp., Knoxville, Tenn. TAPPI Fluid Mechanics Committee chairman; William R. Willets, assistant manager of the Technical Services Laboratories of Titanium Pigment Corporation, New York City. Mr. Willets is secretary of the American Society of Rheology and chairman of the TAPPI Fillers and Pigments Testing Committee.

Donofrio discussed the physical chemistry aspects of beating; Mr. Hobbs, the aging properties of paper; Mr. Beckett, the economic outlook of the paper industry; Mr. Lee, problems encountered in forming a sheet of paper; Mr. Willets, the rheology of paper coatings.

Syracuse

College men and women majoring in science at 60 to 100 colleges and universities east of the Mississippi are expected to attend and participate in the Fifteenth Annual Eastern Colleges Science Conference to be held May 4, 5, and 6, 1961, at the State University College of Forestry at Syracuse University, it was announced today.

Purpose of the 1961 Science Conference is to encourage undergraduate research by:

1. Providing a forum for the presentation of research papers by college undergraduates;

2. Offering undergraduates an opportunity to meet research scientists and hear them present papers; and

3. Programming educational field trips to places of scientific interest.

More than 100 papers will be delivered by college men and women at the conference.

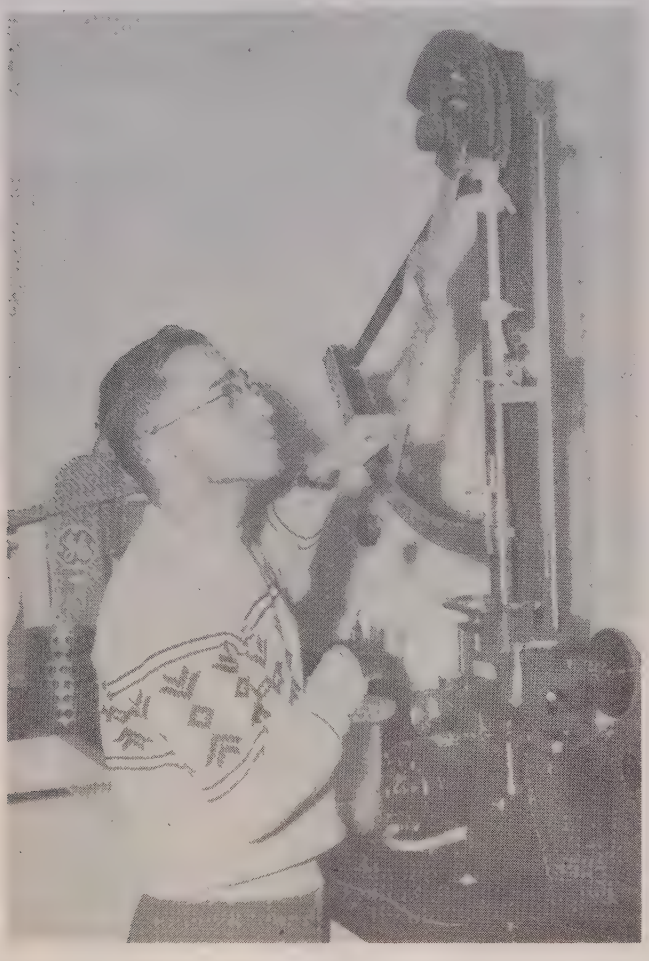
Further information may be obtained by contacting: Robert A. Murphy, Student Chairman, 15th Annual Eastern Colleges Science Conference, State University College of Forestry at Syracuse University, Syracuse 10, N. Y.

KEY
CHEMICALS
for brighter
boxboard
at lower cost
PURECAL® O . . . a Wyandotte Key Chemical
PURECAL O is a fine precipitated calcium carbonate specially developed for paper and paperboard coatings. It is exceptionally pure, white, and uniform. It provides more whiteness than any other coating medium in its price range. Find out how this Wyandotte Key Chemical can help you get crisper colors on cartons, at lower cost.
WYANDOTTE
CHEMICALS
MICHIGAN ALKALI DIVISION, WYANDOTTE, MICHIGAN

Western Michigan

Last spring Tachipully Bhaskaran won a TAPPI prize for his senior thesis work at Western Michigan University, Kalamazoo.

Now about to complete his formal studies in this country, "Bhas" will leave Western in January and in early February



Tachipully Bhaskaran works with a tensile strength tester in the Western Michigan University paper industry laboratories

will join the staff of the Wiggins Teape Research Group Organization, Beaconsfield, England, as a research associate in paper technology.

Before coming to Western in 1958 from his native Malaya, "Bhas" had had research experience with the Malayan Forest Products Laboratory, after having studied in India and other Southeast Asian countries.

Yale

Forest Pathology Program

The Yale School of Forestry announces a notable expansion in its program of graduate instruction and research in forest pathology. Training offered at the doctoral level will have greater emphasis on physiological and biochemical aspects of forest disease and wood products deterioration problems than heretofore has been available in the United States. At the same time, the conventional program in the descriptive phases of the subject will be maintained, especially at the Master's level. To initiate this new program, the School was appointed Dr. Ellis B. Cowling as Assistant Professor of Forest Pathology, to succeed Dr. J. S. Boyce who retired as Professor Emeritus in 1958. Facilities for instruction and research in physiological as well as descriptive aspects of forest pathology are being installed in the School's new Greeley Memorial Laboratory. Nearly 10,000 acres of School forests are available for field work in three different forest types in New England. The program will be administered by the School of Forestry, in cooperation with the Departments of Botany, Microbiology, and Biochemistry at Yale University, with the Connecticut Agricultural Experiment Station and the Forest Insect and Disease Laboratory of the Northeastern Forest Experiment Station of the U. S. Forest Service.

Industry Suppliers

Louis Allis Co.

A six-page Bulletin 2900 outlines an extensive line of adjustable speed drives from The Louis Allis Co., 427 E. Stewart St., Dept. P, Milwaukee, Wis., for applications in the $^3/_4$ to 2500 hp. drive range.

Alllis-Chalmers Mfg. Co.

Fluid Dynamics Department

Effective immediately, the name of Allis-Chalmers pump and compressor department has been changed to the Fluid Dynamics department. Allis-Chalmers has been manufacturing and selling fluid machinery for many years. The change in name has been made to more properly identify the company's ability to meet today's requirements for supplying fluid systems rather than just products.

Motor Controller

Design and operating features of a new concept in high voltage control—the SpaceMaker controller—are described in a new bulletin (14B9739) released by Allis-Chalmers.

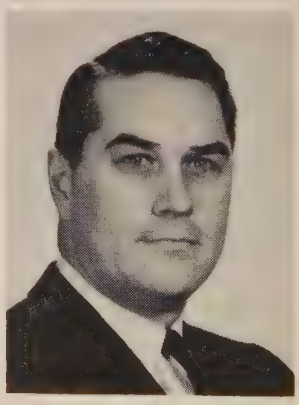
The SpaceMaker controller is the first starter in the 2000 to 5000-v. range to employ a two-high motor control center design. It is the first completely drawout control on the market in this voltage class. It is the lightest weight controller—about $^1/_2$ the weight of present design. The controller is available for squirrel-cage, wound-rotor, and synchronous motors up to 2500 hp. at 4 to 5 kv. and 1500 hp. at 2.3 kv. in reversing or nonreversing, full-voltage, or reduced-voltage starting.

Copies of the new SpaceMaker motor controller bulletin, 14B9739, are available on request from Allis-Chalmers, Milwaukee 1, Wis.

Appleton Woolen Mills

In a move to strengthen the sales and service of its papermakers' felts, Appleton Woolen Mills today announced the establishment of a Product Services Department. Claire Turner, formerly sales manager, was named director of the new department. It will be responsible for product design, customer technical service and liaison, quality control, and inspection. Succeeding Mr. Turner as sales manager is

Claire Turner, Appleton Woolen Mills



R. C. Watts, Appleton Woolen Mills

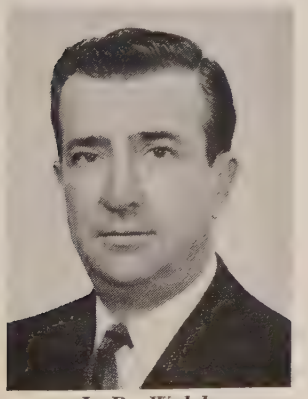
Ralph C. Watts, who had been district sales manager of UARCO, Inc., Chicago, before joining the Appleton felt manufacturing firm.

Beloit Eastern Corp.

The Board of Directors of Beloit Eastern Corp. recently elected W. S. Wood, chairman of the board and E. H. Neese, Jr., president and general manager of their plant in Downingtown, Pa. John R. Walsh, formerly vice-president and general manager,

W. S. Wood,
Beloit Eastern Corp.

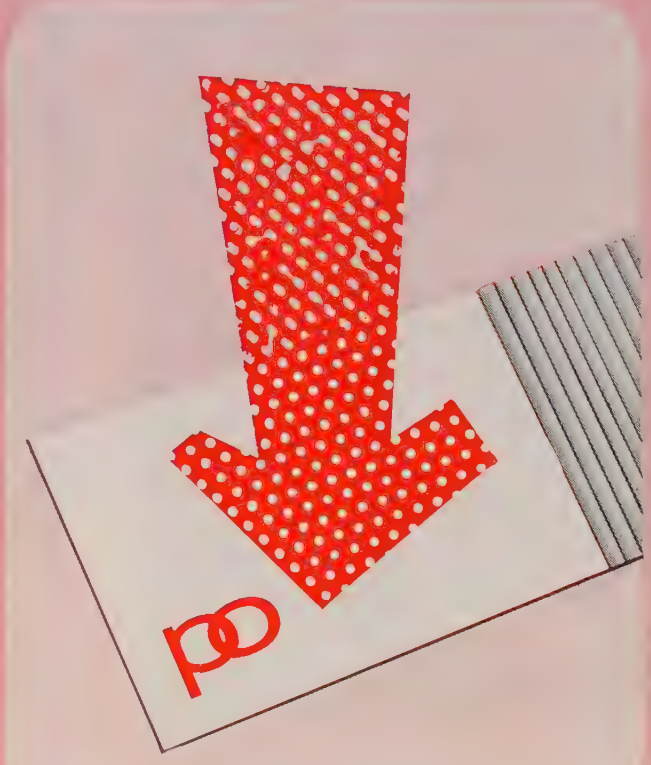
E. H. Nesse, Jr.,
Beloit Eastern Corp.



J. R. Walsh,
Beloit Eastern Corp.

has been appointed vice-president and general plant manager of Beloit Iron Works, Beloit, Wis. Mr. Walsh's appointment fills the vacancy left by W. E. Watson's recent appointment as president, Beloit International Corp., C.A., Zurich, Switzerland.

for smoother surfaces at lower cost



PURECAL® O . . . a Wyandotte Key Chemical

This Wyandotte Key Chemical for papermakers is a precipitated calcium carbonate produced by a unique double-refining process that assures exceptional whiteness, purity, and uniformity of particle size. Result: PURECAL O helps make paper surfaces smoother and whiter, and provides extra hiding power. See for yourself . . . call in your Wyandotte representative.

WYANDOTTE CHEMICALS

MICHIGAN ALKALI DIVISION, WYANDOTTE, MICHIGAN

Black-Clawson Co.

Sweden

The Black-Clawson Co., manufacturer of pulp and paper mill equipment, has expanded sales service to the mills of Sweden with the formation of Black-Clawson (Sweden) A.B. it was announced by Frank Peterson, president of the parent firm. The new company will conduct sales and technical service in Sweden of all Black-Clawson equipment manufactured by the American and British plants of the company and of certain Black-Clawson products manufactured under license by Oy Tampella, A.B., Tammerfors, Finland.

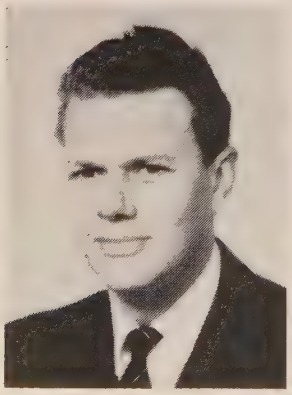
Bo Rosen was appointed manager of Black-Clawson (Sweden), with headquarters at Sveavagen 21, Stockholn.

Don H. Montville

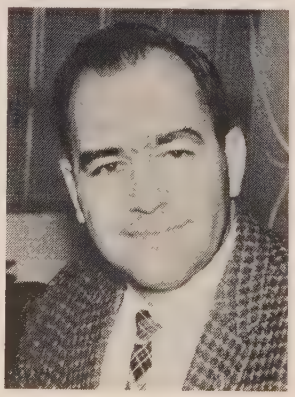
Don H. Montville, vice-president and director of sales for the Shartle Div. of The Black-Clawson Co., recently received a diamond emblem to commemorate his 40 years with the company. Mr. Montville began his career with the company

Black-Clawson Vice-President Don H. Montville receives 40-year pin from Vice-President and Division General Manager Robert F. Vokes

as a salesman for the Shartle Brothers Machine Co. in 1920. He was named assistant sales manager in 1947, after Shartle had become a division of Black-Clawson, producing its stock preparation equipment line. He was promoted to sales manager in 1954 and in 1958 was named vice-president. He has been in his present position of director of sales since 1959.



Bo Rosen, Black-Clawson (Sweden)



R. E. Ingison, Black-Clawson Co., Dilts Div.

Dilts Div.

The appointment of Robert E. Ingison as Technical Director for the Dilts Division of the Black-Clawson Company, Fulton, N. Y. has been announced. Mr. Ingison will be responsible for the administrative and operating functions of the converting laboratories of the Dilts Division, which designs and manufactures the coating and converting equipment of the Black-Clawson product line.

John W. Bolton & Sons, Inc.

Subject of 14th Bolton Award Contest

"Privileges of the Free Enterprise System" is the subject of the 1961 Bolton Award Essay Contest according to a joint announcement made by the Paper Industry Management Association, Chicago, Illinois, and John W. Bolton & Sons, Inc., Lawrence, Massachusetts, cosponsors of the contest. This is the 14th in a series of annual essay contests on subjects of timely significance to all members of industry. The contest is open to all persons engaged in the pulp, paper, and paper converting industry in the United States and Canada. The contest period extends from January 1, 1961, until midnight March 31, 1961.

Doctor Blades

John W. Bolton & Sons, Inc., since 1905 manfacturers of machinery and equipment for the papermaking industry, has added the production of doctor blades of all types to its industrial knife division. Bolton quality doctor blades are now available in all sizes and types in the following materials: tempered carbon steel, cold rolled steel, stainless steel, K-Monel steel, phosphor bronze, laminated plastic, special alloys, and materials for special applications.

Illustrated Bulletin DB-61 on Bolton quality doctor blades is available on request to Machine Knife Div., John W. Bolton & Sons, Inc., Lawrence, Mass.

Borden Chemical Co.

Development of a new prime coat system specifically designed to increase the adhesive properties of hot polyethylene extrusions to cellophane and foils has been announced by the Adhesives & Chemicals Div. of The Borden Chemical Co. Called Borden's SO-242, the product is applied directly to the cellophane or foil by wash coat prior to the extrusion of polyethylene and then air dried. Coverage is rated at less than $^1/_{10}$ lb. per 3000 sq. ft. of dry ream.

For further information write Department H, The Borden Chemical Co., 350 Madison Ave., New York 17, N. Y.

Bowen Engineering, Inc.

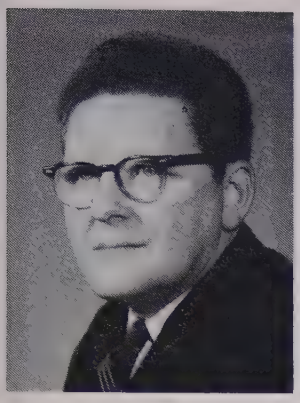
A four-page bulletin (Bulletin 37) discussing special-design spray driers for pilot plant and hard-to-dry materials, and moderate-production driers (up to 20 tons a day), now is available from Bowen Engineering, Inc., North Branch, N. J., the nation's largest spray drying engineering company

Brooks Instrument Co., Inc.

New Bulletin No. 131, now ready for distribution, covers Model Series No. 1400, designed for pressure up to 5000 p.s.i.g. at 200°F. This bulletin incorporates detailed drawings, dimensions, and capacity tables with full description of the No. 1400 Series and its operation. For copies write: Brooks Instrument Co., Inc., Hatfield, Pa.

Chain Belt Co.

Publication of a new 24-page components bulletin, No. 6057P, for Rex-Rated bucket elevators has been announced



O. F. Hutchinson, Peter Cooper, Corp.

M. A. Freytag, Draper Bros. Co.

by Chain Belt Co., Milwaukee, Wis. Bulletin 6057P features simplified selection charts and informational aids which allow quick and easy selection of centrifugal and continuous discharge elevator components. It contains basic data on such Rex components as chains, buckets, sprockets, bearings, and take-ups.

Peter Cooper Corp.

Peter Cooper Corp., manufacturers of animal glues, sizing gelatines, and specialty products for papermaking, have named Orton F. Hutchinson, manager of sales to the paper industry in the United States and Canada. His headquarters will be at the main offices in Gowanda, N. Y.

Draper Bros. Co.

Draper Brothers Co., Canton, Mass., manufacturers of the Draper Felt, announce the appointment of Melvin A. Freytag as their service representative covering the mills in the Midwest area. Mr. Freytag is a graduate of Syracuse University, and has for the past three years been associated with Sealright-Oswego Corporation in the capacity of maintenance engineer.

E. I. du Pont de Nemours & Co.

Grants totaling more than $1,400,000 have been awarded to 159 universities and colleges in the du Pont Co.'s annual program of aid to education, the company announced today.

The program is for fundamental research by universities, for strengthening the teaching of science and related subjects, and for facilities for education or research in science and engineering.

The largest part of the program is to help strengthen the education of scientists and engineers. Grants totaling $654,000 were awarded for the 1961–62 academic year to more than 100 colleges and universities to support the teaching of science and mathematics as well as other liberal arts subjects; for education and research in biochemistry in medical schools; and for postgraduate teaching assistant awards and scholarships for prospective high school teachers of science and mathematics.

Grants for fundamental research in 1961–62 total $475,000 for 37 universities. These are for unrestricted research in the physical sciences, including chemistry, chemical engineering, physics, mechanical engineering, and metallurgy. They range from $5,000 to $20,000. The institutions may use them any way they wish, including the support of graduate students. The universities determine the research to be undertaken and are free to publish the results. An additional $50,400 was awarded for 28 summer research grants to enable individual staff members of 24 universities to undertake research of their own choosing during the summer.

A $250,000 fund was authorized for capital grants for science and engineering facilities. This provided awards to 11 independently controlled institutions. Ranging from $5000 to $50,000 each, these grants to help with the cost of new buildings, equipment, or renovation of existing facilities.

Fischer & Porter Co.

An armored, glass tube, variable-area indicating flowmeter designed for high pressure and temperature service is described in a specification bulletin released by Fischer & Porter Co., Warminster, Pa. The meter is designed so that fluid pressure completely surrounds the glass tube, thereby eliminating tube breakage due to high pressures. Materials of construction, mounting, scales, capacities, and dimensions are given.

For a free copy of Bulletin 10A2147, write Fischer & Porter Co., 800 Jacksonville Road, Warminster, Pa.

General Dyestuff Co.

A new direct dye for producing bright yellow shades on paper, Stilbene Yellow 10 GP, is announced by General Aniline & Film Corp., New York, N. Y. Available through the manufacturer's General Dyestuff Company Div., the new product has exceptional color interest for makers of bond, register, tablet, and other paper grades. Stilbene Yellow 10 GP yields a bright greenish yellow of high tinctorial value for economical dyeing of a variety of sized papers. It is used principally in dyeing lively canary and green shades in customary pastel to medium depths. The product's color value adds new economy to the production of these bright shades.

Highlighted by good buildup on sized papers, the dye's working properties are very satisfactory in running self or combination shades. Light fastness of the new color is comparable to that of other Stilbene Yellow types.

The new dye is best applied in the beater to bleached chemical pulp. Dyeing of sized stock follows conventional methods in either batch or continuous application. In batch dyeing the color can be added dry without causing specking. The product is supplied as a fine nondusting powder.

Additional information on Stilbene Yellow 10 GP, concerning the dye's shade, working properties, fastness, and uses, may be obtained from General Dyestuff Co., a Div. of General Aniline & Film Corp., 435 Hudson St., New York 14, N. Y.

General Electric Co.

Thinline Motors

New Thinline Motors—GEA-6927B—eight-page publication lists features and advantages of General Electric's new Thinline motors for limited space applications. Illustrated bulletin shows full line of Thinline motors rated 1 through 5 hp. in both dripproof and enclosed construction.—General Electric Co., Schenectady 5, N. Y.

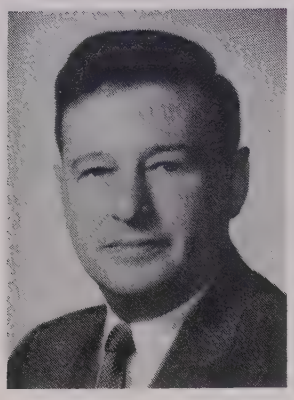
Limit Switch

A new open precision snap-action limit switch designed to bridge the gap between the very small and somewhat fragile limit switches and the larger, enclosed limit switches has been added to General Electric's control line. The new unit will handle high accuracy, fast response applications where space is limited, according to engineers at GE's General Purpose Control Dept., Bloomington, Ill.

Gould Pumps, Inc.

Pumps

New sizes have been added to the Model 3405 line of single stage, double suction centrifugal pumps manufactured by Goulds Pumps, Inc., Seneca Falls, N. Y. Complete specifications, interchangeability chart, performance curves, and dimensions are shown in new Bulletin No. 721.6 available on request from Goulds Pumps, Inc., 219 Black Brook Road, Seneca Falls, N. Y.



S. A. Bunis, Goulds Pumps, Inc.

A. G. Dreis, Heyden Newport Chemical Corp.

P. L. Courtney, J. M. Huber Corp.

J. R. Barnes, Inta-Roto Machine Co.

Staff

S. A. Bunis has been named sales manager of Goulds Pumps, Inc. Associated with the company for 23 years, he has held the position of assistant sales manager for the past four years.

Hamblet Machine Co.

Hamblet Machine Co. of Lawrence, Mass., has introduced Model MDS, a newly designed cutter to handle up to 100-in. wide rolls. This cutter is the result of six decades of engineering and manufacturing for finishing room machinery for the paper and allied industries. Hamblet's MDS design simplicity offers safer operation (all drive gears are enclosed), ease of operation (all adjustments are conveniently located), easier maintenance (all lubrication points are quickly accessible), and rotating members are precision balanced to reduce inherent vibrations to below minimum allowable. All this, plus the usual quality of "ribbed construction" to add strength and eliminate bulk to supporting structures, coupled with optional P.I.V., with integral differential for extreme accuracy, offer converters a revolutionary cutter of unusual performance.

Write to Hamblet Machine Co., Island Street, Lawrence, Mass., for further information and specifications.

Heyden Newport Chemical Corp.

Arthur G. Dreis has been appointed product sales manager, Paper Chemicals, of the Newport Industries Div. of Heyden Newport Chemical Corp., it was announced today by R. J. Spitz, the division's vice-president in Charge of Sales. A principal of his own consulting firm to the paper chemicals and papermaking industries from 1954 until recently, Mr. Dreis is well known in this new market to which Newport Industries will now sell directly. Newport Industries has a long background as a manufacturer of paper size and other paper chemical constituents. Mr. Dreis will be responsible for preparing marketing programs for these materials and for coordinating development, sales, and technical service on chemicals for the paper industry.

J. M. Huber Corp.

Philip L. Courtney has been named vice-president in charge of the clay division of J. M. Huber Corp., which mines and processes kaolin clays in South Carolina and Georgia for the paper, rubber, and other industries, it was announced by M. W. Huber, president. He succeeds Wilbur J. Driver, who retired February 1 after 34 years with the company.

Charles H. Marvin, Jr., manager of the South Carolina operations, was named assistant vice-president, and Frank M. Gribble was appointed general manager of the Georgia operations.

Simultaneous with these appointments, Mr. Huber announced that the headquarters of the clay division have been transferred from Langley, S. C., to Huber, Ga., which is located in Twiggs County on the outskirts of Macon.

Huyck Felt Co.

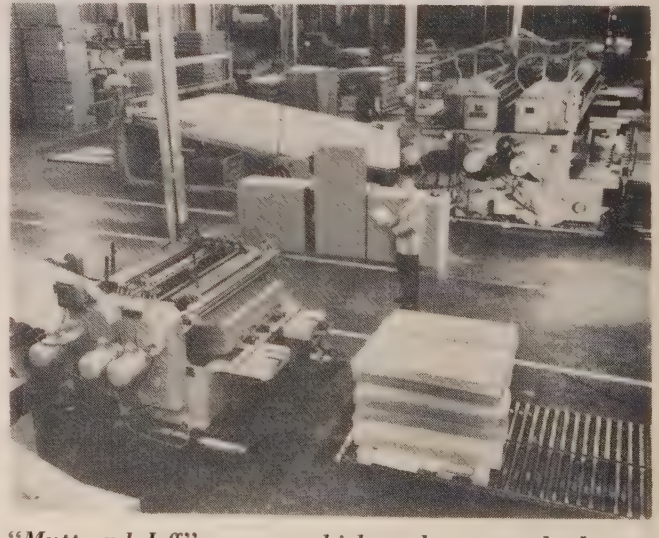
William C. McClure, has been appointed to the position of felt sales engineer for New Hampshire, Vermont, and Northeastern New York by the Huyck Felt Co. of Rensselaer, New York. Prior to this appointment, Mr. McClure served as field assistant to the sales manager.

Infilco, Inc.

T. M. Thompson, president of General American Transportation Corp. of Chicago and J. S. Gustafson, president of Infilco, Inc. of Tucson, announced January 24 that the Chicago corporation has acquired the outstanding stock of Infilco, Inc. Present plans are that the Tucson firm, for sixty-three years a leader in the field of water and waste equipment design and manufacture, will continue to operate under its present management as part of the Fuller group of General American Transportation Corp.

Inta-Roto Machine Co., Inc.

John R. Barnes has been appointed sales engineer by Inta-Roto Machine Company, Inc., Richmond, Va., makers of laminators, rotogravure and flexographic presses, and other machines for the converter. Mr. Barnes come to Inta-Roto



"Mutt and Jeff" presses, which rank among the largest and the smallest ever built for the corrugated paperbox industry, installed side by side in the Los Angeles plant of Container Corp. of America. Both are of Hooper-Swift design, made by the Metal Products Div. of Koppers Co., Inc. The large press is capable of running sheets 80 by 180 in. at the rate of 120 sheets a minute and, with skip feed, can run sheets 100 by 180 in. The small press is capable of running sheets 24 by 66 in. at a rate of 350 sheets per minute. Both presses are two-color

after years of experience with Union Bag-Camp Paper Corp. in the production of gummed tapes, waxed papers, printed rolls, and sheets. His most recent activity has been in the development and production of foil and film laminations.

E. D. Jones Corp.

Majestic Jordan

The E. D. Jones Corp., a member of the Beloit Group, has introduced a newly designed jordan . . . the Jones Majestic. According to Jones, the new Majestic will process the widest possible variety of stock—from fine grades to rough board. Depending on the type of stock being processed, and its ultimate use, Majestic jordan refining capacity varies from 100 to 250t ons per day. For full particulars, write to E. D. Jones Corp., Pittsfield, Mass., specifying Bulletin EDJ-1036.

Staff

Charles H. Vickery, vice-president of E. D. Jones Corp. recently appointed W. C. (Bill) Hand as sales engineer covering the territories of Calif., N. M., Ariz., and Hawaii.

Midland-Ross Corp.

J. O. Ross Engineering

The Seattle office of J. O. Ross Engineering, a Div. of Midland-Ross Corp., recently moved into larger quarters. Formerly at 823 Skinner Building, the Ross office is now located at 2909 Third Ave., Seattle 1, Wash.

Paul Goldner is the Seattle district sales manager of Ross Engineering, manufacturers of air processing equipment.

Minneapolis-Honeywell Regulator Co.

A new industrial process potentiometer described as "revolutionary" in concept and made possible by a "scientific breakthrough in the state of the art" has been introduced by Brown Instruments Division of Minneapolis-Honeywell Regulator Co. The new device, called the ElectroniK 17 and incorporating an extremely accurate, trouble-free electromechanical strain gage as the rebalancing element, is expected to open up a new era in precision measurement and recording in industry. In eliminating the conventional slidewire, long an objective of instrumentation engineers, infinite resolution is achieved for the first time in a potentiometer. No longer is the number of points at which a potentiometer can come to balance limited to the turns (convolutions) on a slidewire.

Calibrated accuracy of the ElectroniK 17 is $^1/_4$%. Strip chart instruments have pen speeds of 1, 5, and 15 sec. Those for circular chart instruments are 5 and 15 sec.

Monsanto Chemical Co.

Monsanto Chemical Company has introduced a 45% concentrate white polyethylene which can be blended with any of the company's polyethylene extrusion and film resins to suit specific end use requirements. Designated Monsanto polyethylene 6407, the new concentrate is compounded with Monsanto polyethylene 70 and a rutile titanium dioxide pigment which is said to reduce materially screenpack and nonuniform pigment feed.

Edward R. Tolles, polyethylene sales manager for the company's Plastics Division, said that the new material gives extruders and extrusion coaters maximum inventory control and flexibility and at the same time permits substantial production savings and quality improvements.

New Jersey Zinc Co.

Donald A. Brown has been appointed sales representative for Tenn., Ala., Miss., and La. by The New Jersey Zinc Co.

Revolutionary design concepts that include a unit operating on the proved strain gage principle instead of the conventional slidewire as the rebalancing element are incorporated in new ElectroniK 17 potentiometer developed by Brown Instruments Div. of Minneapolis-Honeywell Regulator Co. Vice-President James S. Locke (left) and J. A. Robinson, divisional sales manager, inspect the Stranducer, a precision electro-mechanical strain gage that is "heart" of measuring system. Stray signal rejection and single reference junction compensation for all types of thermocouples are among other unique features. First production models consist of strip chart and circular chart recorders and circular scale indicator

Nichols Engineering & Research Corp.

Seila Supraton

Nichols Engineering & Research Corp., New York, N. Y., announces that it is now handling the sales of the Seila Supraton, ultrasonic fiber dispersion unit, in the United States, except for seven West Coast area states, covered by Pacific Supraton, Inc., San Francisco, Calif. The Supraton is a compact, flexible unit with low power requirements. It will handle paper stock at consistencies of 2 to 8%. Capacity range is 1500 to 4000 lb. per hr. The Supraton affords complete dispersal of fibers in furnishes of dried pulp, waste papers, machine broke, including wet strength and deinked stocks, without cutting or hydration.

Spray Drier

Marathon, Division of American Can Company, is showing the way to effective stream pollution control by turning its concentrated spent sulfite liquor into a dry product for industrial uses.

The new Nerco-Niro spray drier at Marathon's Green Bay pulp and paper mill provides for 50 tons of finely powdered chemicals now being produced each day and sold under the trade name of "Norlig."

For information about spray drying and its varied applications, write to: Nerco-Niro Spray Dryer Div., Nichols Engineering and Research Corp., 80 Pine St., New York 5, N. Y.

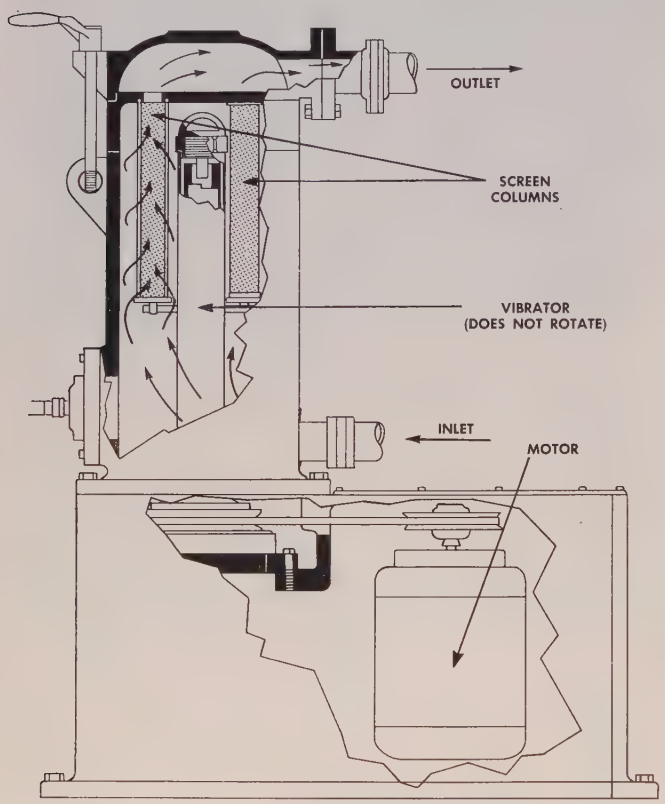
Ohmart Corp.

H. L. Cook has been elected vice-president of The Ohmart Corp., by the firm's board of directors, according to Philip E. Ohmart, president of the Cincinnati nuclear gage manufacturer. Mr. Cook joined the firm in 1951 as an electrical engineer and has been chief engineer since 1954. In his new poistion, he will have expanded responsibilities for new product development and research, acquisition of other businesses, and other administrative duties.

Patton Manufacturing Co.

Pressure Screen for High Solids Color

A new device, the "Z Screen," has been developed primarily for screening high solids coating color. Excellent results have been achieved in screening 50 to 65% solids color. The



Drawing of the Z screen produced by the Patton Manufacturing Co.

pressurized "Z Screen" is patented and is manufactured by Patton Manufacturing Co., Inc., of Springfield, Ohio.

A major advantage of this design is that the screening action takes place under pressure in a closed system. The screen can be installed in a pipeline, permitting clean operation without exposure of the color to air. All screening surfaces are in service all of the time, regardless of flow rate, while the screen is operating.

Perkins-Goodwin Co.

The Board of Directors of Perkins-Goodwin Co., international pulp and paper marketing-management organization, announces the following elections: Louis Calder, Jr., president, has also been elected treasurer; Richard T. Trelfa, executive vice-president; John I. Haney, vice-president and a director; John L. Quackenbush, manager of the Chicago office, vice-president.

Stanford G. Blankinship has submitted his resignation as vice-president, but will continue to serve as a director and consultant.

Pflaudler Permutit, Inc.

Pfaudler Co.

An eight-page bulletin Bulletin 1001 describing features of the new "TW drive" is now available from The Pfaudler Co., division of Pfaudler Permutit, Inc., Rochester, N. Y., specialists in fluid handling equipment. The TW drive is designed to provide quiet, low-cost agitation in open or closed chemical vessels. It is available with either seal or stuffing box—depending primarily upon how corrosive an environment is involved—and fixed or variable speed belts, fixed speed gears, or hydraulic systems can be provided.

Glassed-Metal Pipe, Valves, and Fittings

A new 16-page bulletin No. 987 is available which describes glassed-metal pipe, valves, and fittings manufactured by The Pfaudler Co.

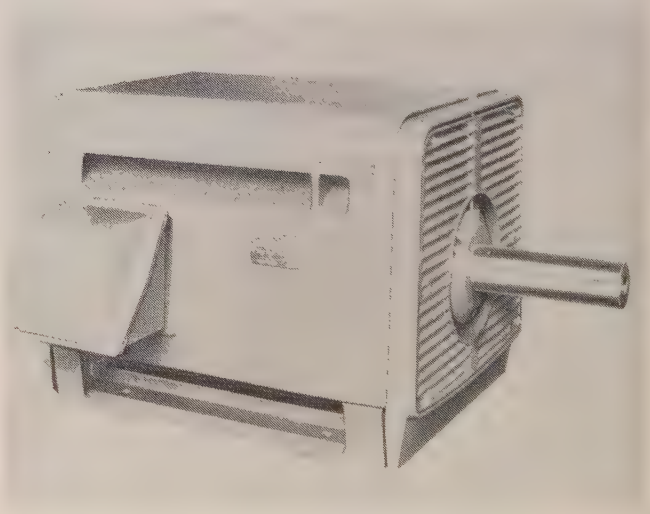
Copies of the new literature may be obtained by requesting the bulletins from The Pfaudler Co., 1127 West Ave., Rochester 11, N. Y.

Ionac Chemical

Two new dry-type chemical treatments for boiler and process systems—an alkalinity-pH depressant and an acid cleaner—have been introduced by Ionac Chemical Co., a Div. of Pfaudler Permutit, Inc., at Birmingham, N. J. Both the new chemicals are based on sulfamic acid and have a wide range of application in cleaning boilers, heat exchangers, condensers, evaporators, cooling jackets, process vessels, and piping.

Reliance Electric & Engineering Co.

The Reliance Electric and Engineering Co., Cleveland, Ohio has developed a new motor, called the Duty Master D-5000, which has a round stator inside its nearly square frame. This unusual arrangement provides better cooling,



Reliance Duty Master D-5000 motor

permitting using a smaller overall dimension for any given horsepower rating. The D-5000, which is available from 125 through 300 hp., has large air intakes which cover each end of the motor. Air is drawn in these louvered openings, ducted through the rotor and stator, and then exhausted at the sides.

Duty Master Motor Bulletin

The Reliance Electric and Engineering Co. offers a comprehensive bulletin on their fractional horsepower Duty Master motor.

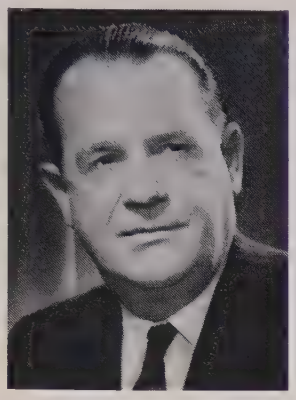
The eight-page bulletin gives a comprehensive description of the construction and design details of the new Duty Master FHP. Each point is illustrated with photos and drawings, and a life size photo of a cut-away motor is shown in full

color. For further information write for Bulletin B-2514. Reliance Electric and Engineering Company, Cleveland 17, Ohio.

Rice Barton Corp.

Donald B. DeNoyer, vice-president in charge of engineering of Rice Barton Corp., Worcester, Mass., has announced the appointment of John C. Gresham as chief engineer of special products. Mr. Gresham will be responsible for the development and application of specialized papermaking machinery

J. C. Gresham, Rice Barton Corp.



A. J. Reichers, Rice Barton Corp.

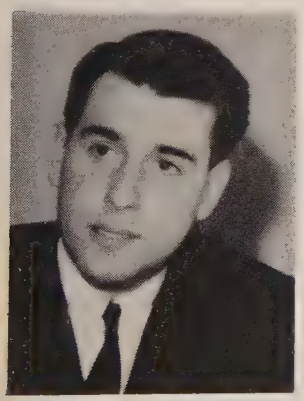
equipment, with particular emphasis on coater ranges, converting machinery, and drives. He has been instrumental in improving the drive on Rice Barton's new trailing blade coater range and high speed automatic paster.

Albert J. Reichers has also joined Rice Barton as manager of manufacturing. Prior to joining Rice Barton, Mr. Reichers was plant manager for Cooper Alloys of Hillside, N. J. As plant manager, he supervised production control, manufacturing engineering, plant engineering, and production activities at Cooper.

E. H. Eggleston, S & S Corrugated Paper Machinery Co.

S & S Corrugated Paper Machinery Co.

S & S Corrugated Paper Machinery Co., Inc., Brooklyn, N. Y., announces the expansion of its sales engineering group by the appointment of three additional men. Eugene H. Eggleston, formerly with E. F. Houghton & Co., has been assigned to cover the Mississippi Valley region, with headquarters in St. Louis. The New England States will be covered by Charles G. Janis, who formerly was in charge of Western States technical sales for Stein-Hall Co. Peter W. Hegener, sales engineer in the S & S Export Division, with offices at S & S headquarters, was associated with the export division of Worthington Company.



C. G. Javis, S & S Corrugated Paper Machinery Co.

P. W. Hegener, S & S Corrugated Paper Machinery Co.

A. E. Staley Mfg. Co.

A production process for separating pure amylose and amylopectin fractions from ordinary dent corn—something sought by many starch scientists for a long time—was announced today by the A. E. Staley Manufacturing Co.

Board Chairman A. E. Staley, Jr., of the Decatur corn, soybean, and chemical processing concern said the company has completed and put in operation at Decatur a pilot plant which is now fractionating starch. It is separating the two basic starch components in semicommercial quantities and in reasonable degrees of purity.

The separated components can be used individually or recombined in any ratio to tailor characteristics of the highly-branched amylopectin polymer and the linear-structured amylose polymer to any specific application.

Amylose is chemically similar to cellulose, and although different in molecular structure and physical properties, has the added advantage of being edible. Among such possibilities for exploring and developing uses for amylose, are transparent films, plastics, coating applications of all sorts, fibers, and filaments. These possibilities are of particular interest in the textile, paper, and related industries.

Initial use for the amylopectin fraction appears to be in the food industry, where a large market already exists for amylopectin derived from waxy maize, and intermix possibilities in the whole range of industrial starch applications are being explored.

The new series of Staley starch products has been given the brand name "Napol," with the designations "L" for the pure amylose linear polymer and "B" for the amylopectin branched polymer.

Taylor Instrument Cos.

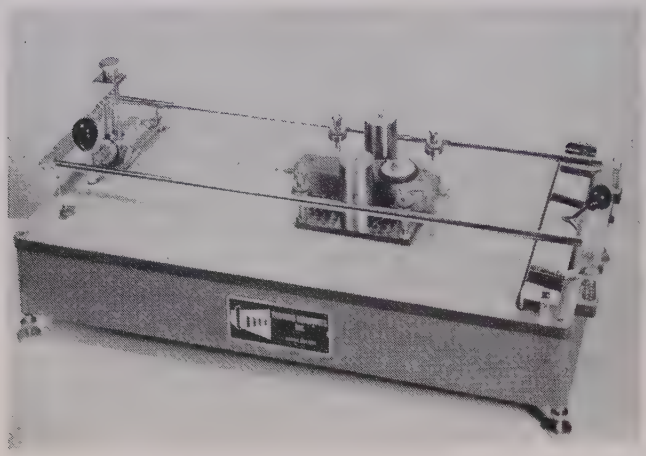
The newest of Taylor Instrument Cos. subsidiaries will begin operations in April of this year. Taylor Instrument, Mexico, S. A., is located less than six miles from Mexico City. The new company will do some local manufacturing and handle instrument assembly and repair. To the present the Taylor operation in Mexico has been handled by Martinez S. de R. L. Personnel from this organization will continue to handle sales in Mexico. The new company brings to a total of eight, the number of Taylor subsidiaries operating throughout the world.

Testing Machines, Inc.

W. F. Bachelder of Testing Machines, Inc., returned to the United States late in 1960 from an extensive trip through England and Continental Europe investigating latest testing and quality control methods and related equipment. He found much emphasis being placed on automated process control equipment. In addition to the function of inspection, much of this equipment has automatic feed back to control the output of production machinery. In the laboratories emphasis is being placed on electronic devices for the measurement of moisture, relative humidity, and physical tests. The most suitable of the new techniques and devices will be added to the TMI line of testing machines and the more useful points of information will be disseminated in forthcoming issues of the TMI news bulletin *"Testing USA."*

Slip & Friction Tester for Static or Sliding Tests

The new TMI slip & friction tester is ruggedly constructed with constant speed drive and dead weight platen pressure. The moving platen shown in the center of the photograph,



TMI slip and friction tester

has a force gage mounted on it. The force gage registers the maximum force for determining the static (starting) friction, or the force gage converts to the continuously indicating type so that readings can be taken over the entire surface of the material being tested and averaged out to obtain the dynamic or sliding friction.

Depending upon the characteristics of the material being tested, the small center platen can be used by itself, or it can be attached to a larger platen for use on larger samples.

Sixteen additional weights are included so that the platen weights can be increased as desired.

For complete information write to Testing Machines, Inc., 72 Jericho Turnpike, Mineola, N. Y.

Sample Extractor

A new sample extractor is now available for quality control or testing. It is used to take samples from deep within shipping sacks, bags, bales, and containers. Samples of chemicals, cosmetics, soft drinks, grain seed, fertilizer, and chips can be taken. Two models go a maximum depth of 24 or 48 in. with sampling chamber sizes of $2 \times {}^{15}/_{16}$ in. or 6×2-in.

Thwing-Albert Instrument Co.

Bulletin No. 373-ST describing the Fotosize liquid penetration tester for sizing of paper is available. The bulletin illustrates the photoelectric Fotosize tester and describes the operation of the instrument that can be operated by untrained personnel to get accurate and reproducible results.

Texas Gulf Sulphur Co.

S.S. Marine Sulphur Queen

The *S.S. Marine Sulphur Queen,* an ocean-going tanker capable of hauling 15,100 tons of molten sulfur, has been put into service. It is the first ocean-going vessel in the sulfur industry to be devoted exclusively to the transport of molten sulfur.

The *Marine Sulphur Queen* is a converted T-2 tanker and will be used by Texas Gulf to transport sulfur from its main storage and loading terminal at Beaumont, Tex., to two new molten sulfur terminals at Carteret, N. J., and Norfolk, Va.

The 523-ft. vessel has four separate insulated cargo tanks. For sulfur to remain fluid, it must be kept at a temperature of 275°F. The tanks are steam-heated by means of internal pipe coils fed by two boilers capable of producing 32,000 lb. of steam per hour. Need for constant temperatures is due to the peculiar physical characteristics of sulfur; below 240°F. it begins to solidify and above 320°F. it becomes viscous.

The new cargo carrier and the two new East Coast terminals represent important additions to Texas Gulf's overall program of expanding shipments of sulfur in molten, or liquid, form.

W. S. Tyler Co.

Culminating many years of development including four years of actual field testing, The W. S. Tyler Co., of Cleveland, Ohio, has announced a new type of fourdrinier paper machine wire, called Ty-Flex. It is made of stainless steel—the first successful use of this material for fourdrinier machine application.

W. S. Tyler states that the product development was started in response to a need by the paper industry for a more durable material that would resist both excessive corrosion and abrasion better than either the plain or plated phosphor bronze wires normally used. In semichemical mills particularly, the problems of corrosion and abrasion result in a relatively short life for fourdrinier wires.

While it is well known that stainless steel has superior corrosion and abrasion resistance properties, two problems unique to paper machine application had to be overcome. First was developing a stainless steel wire which would permit the high speed flexing encountered on modern paper machines. The second was devising a method of seaming the wire cloth to form an endless belt, which would also withstand the corrosive and abrasive conditions encountered. Both obstacles have been successfully solved with the new Ty-Flex wire on which United States and foreign patents are pending. Flexibility of the stainless steel cloth, which can be woven in plain, semi-twill, or full twill weave, is comparable to cloth made of bronze alloys.

The new Tyler wire is now being produced in regular meshes and wire diameters, which can be used on existing equipment without any modification.

Virginia Smelting Co.

M. A. Kise, director of research and development for the Virginia Smelting Co., a nationally known chemical manufacturer, recently announced the appointment of E. B. Hotelling to the newly created position of associate director of research. As associate director, Dr. Hotelling will spearhead Virginia's new product development program from the company's research center and executive headquarters in West Norfolk, Va.

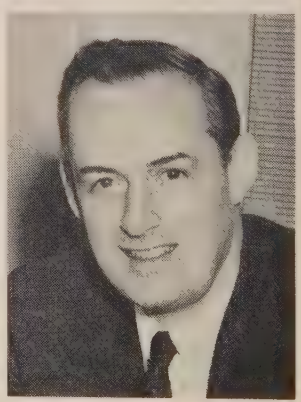
Wallace & Tiernan, Inc.

Metering Pump

Wallace & Tiernan, Inc., Belleville, N. J., has added another model, the Series 100, to its line of plunger metering pumps. The Series 100 is the smallest in the W&T plunger pump line, and is designed to give accurate, economical metering against pressures up to 1200 psi. Capacities range from 0.95 g.p.h. versus 1200 p.s.i., to 50 g.p.h. versus 100 p.s.i., at repeatable accuracies within $\pm 1\%$.

Staff

Wallace & Tiernan, Inc., announces that Henry C. Marks, previously director of research for its chemical and pharmaceutical divisions in Belleville, will become director of research for all company divisions. Dr. Marks was born in Philadelphia, and is a graduate of the University of Pennsylvania with a B.A. in Chemistry. He also holds a Ph.D. in Chemistry from Columbia University.



H. C. Marks, Wallace & Tiernan, Inc.

Wisconsin Wire Works

The new Lev-L-Weve fourdrinier wire, being introduced by Wisconsin Wire Works, was the principal subject at a recent special sales meeting held at the plant here. The field repre-

W. G. Price; J. E. Watson, president and general manager of the Wisconsin Wire Works; H. B. Hill, Jr.; and D. A. Krueger. Top Row: L. G. Mortell; W. N. Dreyer; G. T. Clayton; N. J. McCurdie; J. F. Howell and N. R. Dover. F. J. Halloin and V. S. Risley, Jr. not photographed

sentatives were instructed in the advantages and the cost-saving features of Wisconsin's exclusive Lev-L-Weve, the first new fourdrinier wire in over 27 years. And, they had on-the-job training in the various production phases of the new wire.

General

Corn Refiners 1960 Production

Floyd J. Hosking, executive vice-president of Corn Industries Research Foundation, Inc., representing the eleven firms which comprise the U. S. corn-refining industry, said today that the industry's total shipments of finished products amounted to the equivalent of 153,470,805 bushels of corn in 1960. This figure is slightly over the previous record of 153,226,281 bushels in 1959, and represents 74% of the industry's capacity.

Mr. Hosking expressed concern over growing imports of duty-free tapioca and other foreign starches, which amounted to some 300 million lb. in 1960.

Forest Products Laboratory Reports

Eight new or revised reports dealing with wood and its related subjects have been issued by the U. S. Forest Products Laboratory.

In Report 2202, "The Performance of Wood in Fire," are presented some research accomplishments in the field of pyrolysis and combustion of wood.

Various means of checking the retention and penetration of preservatives in treated poles are described in Report 2206, "Inspection of Preservative Treatment of Poles."

Experiments leading to the development of tempered hardboards from Ohia, a major species growing in the Hawaiian Islands, are presented in Report 2205, "Hardboard from Ohia."

The expansion and contraction of free films of house paints with changes in temperature are described in Report 2204, "Thermal Expansion of Free Films of House Paint."

In Report 2164, "Drying Stresses and Stress Relief in Thin Sections of Wood," is explained a method to evaluate stresses and strains in case hardened veneer by measuring the bowing of slices cut parallel to the veneer surface.

Revised and brought up to date are three lists of publications that include Report 238, "Chemistry of Wood and Derived Products"; Report 790, Logging, Milling, and Utilization of Timber Products"; and Report 508, "Fungus Defects in Forest Products and Decay in Trees."

Safety

Floor Treatment

Safety in a knife-grinding machine surface area in the Lincoln, Me., plant of Standard Packaging Corp. has increased greatly through use of a nonskid material that offsets slip hazards caused by dripping lubricant and water.

This product, Dura-Grip, supplied by Mine Safety Appliances Company, Pittsburgh, Pa., is a bonding resin impregnated with aluminum oxide grit particles. First coat of the bonding compound was applied and then the abrasive material sprinkled on lightly. After an hour's drying time, excess grit was swept off and a second coat of the gray bonding mix applied. The surface dried for use in 6 hr.

Spending for Chemicals

Each American now spends about $156 a year for chemicals and chemical products.

Reaching back to 1899, Americans spent a mere $17.63 when the annual value of chemical shipments stood at $1.32 billion. But by 1939, they had increased their per capita expenditures to $33.38.

At the same time they were spending more, they required more also. For instance, in 1939 per capita production of sulfuric acid amounted to almost 74 lb., rising to an estimated 190 lb. in 1960. Ammonia consumption for 1939 was little more than 7 lb., for 1960 it was nearly 55 lb.

The same story is true for chlorine, 8 lb. in 1939 and about 51 in 1960; and caustic soda, 16 lb. in 1939 and nearly 55 lb. today.

The biggest jump has come in the last 20 years spurred by the demand for such products as plastics, man-made fibers, fertilizers, synthetic detergents, and antibiotics.

—*Chemical News* **7**, No. 5 (Nov.–Dec., 1960)

Journal of Russian and Eastern Translations

A new technical journal, to be published quarterly by the American Institute of Chemical Engineers, beginning in October, will be known as *International Chemical Engineering*, F. J. Van Antwerpen, AIChE secretary, has announced.

The journal will contain translations of articles on chemical engineering developments in Russia, Eastern and Central Europe and communist China. The editor is Waldo Hoffman, former senior associate editor of *Chemical Engineering Progress*, and a linguist.

Articles to be translated will be selected by an advisory board. This board includes several of this country's leading chemical engineers, and a large number of specialists who have offered their services to AIChE as contributions toward fuller awareness of chemical engineering activities in other parts of the world where the language barrier constitutes a formidable obstacle for most of our chemical engineers.

The project is sponsored by the National Science Foundation.

Color Trends in America

Color trends in American exist for the simple reason that people seldom want the same thing twice. They exist also because of a high standard of living in which factors of appearance are in every way as important to the good life as price and utility.

The American economy is often criticized for "forced obsolescence." Color admits no such indictment, for it symbolizes pleasure in beauty—the new suit or dress, the new furniture, coat of paint, which give dignity and attraction to life and have great tangible worth.

Color trends in high fashion move in rapid cycles, and certain of its fancies enter volume fields where the cycles are slower. In home furnishings, a full turn of preference will usually take about ten years: from colors of bright contrast, to pastels, to muted hues and back again to the more vivid palette.

Color may have intrinsic charm—like music and painting—but human taste is discriminating. In commercial products, in many forms of printing and advertising, change is the constant order of the day. What was liked yesterday may be rejected tomorrow.

What is strange about color is the fact that trends never seem to get out of hand. The shift from old colors to new ones will follow a fairly consistent pattern. While this may be difficult to predict, intelligent research can be used to plot a reliably accurate course and to mark likely channels of color acceptance for the future.

In a big and general way, sharp colors and deep colors were wanted a decade ago. The movement was then toward light tones and pastels—plus certain "earth" colors such as beige.

America has just about passed the peak of the pastel range, the cycle is turning fast, and the nation is now embarking upon another bold expression.

As to actual hues, the once dominant popularity of ivory (in home furnishings, paints), has fallen off markedly. Greens which went down at the expense of beige will probably return, but not for a while. Light cool greens are good today, but not chartreuse or deep green. (Fern green is excellent in high fashion.)

Gray has declined, and preferred tones are on the warm side. Yellow has been steady. Pink has risen and then fallen. Turquoise has been the most popular of the blues but has recently eased off—to be replaced by truer blue.

Off-white has been one of the most pronounced trend colors and has influenced numerous products, telephones, automobiles, even outboard motors. Lilac which has come up suddenly will quite probably go out almost as fast. Red has held its own. Some variations of it will sell well at all times. The old flame red of the fifties will no doubt repeat itself in the sixties.

Orange, a favorite in high fashion, has not taken well in mass markets, except in a few textiles. Otherwise, countless other colors, not charted, lay dormant or waiting to be exploited.

Color is no mere frill or luxury. It has become an economic force in modern business. As such, it must be used with reason and purpose—and sound research is one sure guarantee of effectivness and profits.

FABER BIRREN, *Color Consultant*
General Printing Ink Div.
Sun Chemical Corp.

OBITUARIES

Norman F. Allemore

Norman Francis Allemore, Pulp Mill Superintendent at the St. Joe Paper Co., Port St. Joe, Fla., died of leukemia, Sept. 21, 1960.

Mr. Allemore was born Aug. 17, 1906, in Lake Charles, La. After graduating from high school he went to work for the E. Z. Opener Bag Co. and in 1928 went to the Gulf States Paper Corp., Tuscaloosa, Ala. He joined the St. Joe Paper Co. in 1936.

Mr. Allemore became a member of TAPPI in 1947.

Walter J. Roider, Sr.

Walter J. Roider, Sr., retired, died Jan. 18, 1961, in Bainbridge Hospital, Bainbridge, N. Y., also the location of his home. Formerly superintendent of the Bainbridge plant of the Casein Company of America, later the Casein Department of the Borden Chemical Co., Mr. Roider participated in the development of a number of products for the paper industry. He is survived by his widow and a son, Walter J. Roider, Jr., Borden Chemical Company, New York, N. Y.

Mr. Roider was the company representative for the Borden Co. in TAPPI.

Richard Irwin Rush

Dr. Richard Irwin Rush, 60, widely known chemist who had served as professor of chemistry and department head since 1927 at Centre College, Danville, Ky., died Thursday morning, Jan. 5, 1961, apparently in his sleep at his home in Danville.

Dr. Rush was a founder and past president of the South Central Independent College Association of Chemists. The group, composed of college chemists of Kentucky and other states of this region, was formed three years ago in order to promote research work in the chemistry departments of independent, liberal arts colleges.

His 34 years of service to Centre was the second longest of any member of the present Centre faculty. He was chairman of the Centre faculty research grant committee and had served as chairman of the school's scholarship committee. In 1954 he was voted by Centre students as "the most popular professor."

Dr. Rush was a pioneer in promoting chemical research in liberal arts colleges. He was head of a research project within the Centre chemistry department for the West Virginia Pulp and Paper Co. of Luke, Md., and New York City.

A native of Woodstock, Va., he was a past president of the Kentucky Association of Chemisty Teachers and a post chairman of the Lexington Section of the American Chemical Society. He had also served as president of the Danville Kiwanis Club and as a ruling elder of the First Presbyterian Church here.

An active leader in Boy Scout work, Dr. Rush was vice-president of the Bluegrass Area Council and chairman of the Danville District Committee for six years. For many years he conducted "Science Headlines," a weekly science news program, on the Danville radio station. He wrote articles for a number of nationally circulated scientific publications, including *Tappi*.

Dr. Rush received the bachelor of arts and doctor-of-philosophy degrees from Johns Hopkins University in Baltimore, Md. In 1941–42 he held a General Education Board Fellowship at the University of Chicago. An avid sports fan, he was teacher and coach in the early 1920's at Bristol, Va., high school.

He is survived by his wife and a son, Richard I. Rush, Jr., research chemist, Oak Ridge, Tenn.

Dr. Rush became a member of TAPPI in 1952.

Twelfth
Coating Conference
Statler-Hilton Hotel, Buffalo, N. Y.
May 8–10, 1961

TAPPI DIVISIONS AND COMMITTEE

Reports of Activities

Authorized Committee Assignments

The following new assignments initiated in committee during the month of January, 1961, constitute the continuing association activities of the committees indicated. These TAPPI assignments are activities that are carried on in addition to the planning of meeting programs. The TAPPI numbers assigned cover the committee work performed in connection with conferences, monographs, standards, data sheets, routine control methods, special reports, conference papers, etc. These numbers are assigned by TAPPI Headquarters.

Assignment no.	*Committee*	*Title and objective*	*Committeeman in charge of assignment*
		COATING AND GRAPHIC ARTS DIVISION	
1000	Coating	"Technical Information Sheets"—to produce technical information sheets in the field of coating technology.	L. E. Georgevits
1001	Coating	"Liaison with Routine Control Methods"—to obtain Routine Control Methods for coating and coating materials and submit them to the RC Methods Committee.	R. I. Bashford
1002	Coating	"Liaison with ASTM D-25"—to keep the Coating Committee informed of the activities of ASTM D-25. Also convey any suggestions of Coating Committee to ASTM D-25.	J. E. Voit
		CORRUGATED CONTAINER DIVISION	
3000	Steering & Advisory	"Fourteenth Corrugated Containers Conference"—1964 Conference to be held in Dallas, Tex.	
		ENGINEERING DIVISION	
4000	Maintenance Engineering	"Maintenance Survey Project"—(a) To compile a statistical report on existing practices and policies, throughout the industry, pertaining to maintenance organization & administration, and the development and performance of maintenance people—both hourly and supervisory. (b) To incorporate whatever opinions and suggestions are available from the above data into a skeleton outline of possible activities which may be helpful as a guide in appraising individual situations.	H. Wayne Smith
4001	Fluid Mechanics	"Flow Through Porous Media"—The objective of this subcommittee is to further define the characteristics of flow through porous media as related to the technology of papermaking. The first activity of this subcommittee was the sponsorship of four papers at the recent division meeting in Jacksonville, Fla. A further program for this subcommittee will be developed between now and October, 1961.	W. I. Ingmanson
4002	Chemical Engineering	"Evaporator Steam Economy"—proposed data sheet.	A. J. Chase
		PULP MANUFACTURING	
6000	Alkaline Pulping	"Revision of T 625 m-48, Analysis of Sulfate Black Liquor"—revising of TAPPI Standard T 625 m-48.	R. Kesler
		RESEARCH & DEVELOPMENT	
7000	Statistics	"EVPO Course—1961"—to hold a 2-day course in evolutionary operation.	M. S. Renner
7001	Statistics	"Statistics Course"—to hold Tenth Statistics Course.	M. S. Renner
7002	Statistics	"Second EVPO Course"—to hold a day course in evolutionary operation.	
7003	Fundamental Research	"Fundamental Research Conference"—to hold a conference in 1962 on the theme "nip phenomena."	R. P. Whitney
		TESTING DIVISION	
8000	Precision	"Precision of Test Methods for Evaluation of Fluorescent Brightness"—under Research Grant No. 135, to provide Precision Committee liaison with assignment No. 794, Evaluation of Fluorescent Brightness.	J. M. Patek
8001	Paper Testing and Physical Methods	"Heat Test for Relative Stability of Paper"—reconfirmation of existing official Standard T 453 m-48.	R. B. Hobbs

Assignment no.	Committee	Title and objective	Committeeman in charge of assignment
8002	Optical Methods	"Apparatus for Photomicrographs of Paperboard Surfaces under Tangent Illumination"—specification for apparatus.	A. Lang
8003	Optical Methods	"Optical Method for Ink-Setting Time"—to prepare optical test method for ink setting time.	R. M. Schaeffer
8004	Optical Methods	"Optical Method for Ink Show Through"—to prepare test for ink show through based on Kubelka Munk Variables.	A. Lang
8005	Physical Methods	"Measurement of Relative Humidity"—to study methods of measuring relative humidity to better determine the exact conditions in the room.	T. W. Lashof
8006	Release Paper Testing	"Adhesive Investigation"—study various tapes, masses, etc., at 90° and 180° pull on given grades of paper and simultaneously accumulate data on various testing materials.	R. Kennedy
8007	Release Paper Testing	"Bibliography of Release Materials"	J. W. Howard
8008	Routine Control	"1961 Proposed RC Methods"—annual gathering of data and methods.	L. J. Slentz

Engineering Division

Chemical Engineering Committee

The committee met Oct. 25, 1961, in Jacksonville, Fla., during the Engineering Conference. Minutes of the previous luncheon meeting at the 45th Annual TAPPI Meeting in New York were read and accepted with a minor correction. John Lewis was erroneously mentioned as vice-president instead of vice-chairman.

E. F. Thode reported on the Operations Research Subcommittee. He explained that this subcommittee is now in an interim period prior to the establishment of a new full committee. E. H. Olmstead is acting as advisor. A subcommittee meeting to be held after this meeting to discuss new committee charter. Four areas of service for new committee include: helping other committees on applied mathematics, cooperation on research projects, educational function on applied mathematics, and the demonstration of automation in the industry.

S. W. McKibbins reported on the Chemical Engineering Subcommittee. Thirty-eight problems have been presented and will be submitted for editing which should be completed in December. They should be presented at the February meeting and then published in loose leaf folder. There are ten major areas of Chemical Engineering problems. Problems will be added as time goes on. The chemical education program for colleges is being withheld for completion of problems.

L. W. Zabel, chairman of the subcommittee on Process Dynamics, reported that he is soliciting members. Mr. Zabel made a motion that a project on the mixing and blending of pulp be submitted for TAPPI approval. This motion was seconded.

Project No. 817 on gas absorption has been submitted for approval. If approved, work will be done by Dr. G. Moon at the University of Cincinnati. This will cover the absorption of sulfur dioxide in a variety of alkaline media.

Chemical Engineering Committee

R. F. Clemens reported that a committee newsletter had been submitted to *Tappi* covering chiefly the activities of our subcommittees and had been well received. A. J. Winchester mentioned that Newsletters should not cover minutes of committee meetings since they are not of interest outside of the committee.

John Lewis reported for A. J. Chase, chairman of the Data Sheet Committee. No new data sheets have been processed but it is expected that some sheets will be prepared for the February meeting. Mr. Chase submitted a letter listing some of the material on hand for processing.

A. W. Plummer announced that TAPPI Headquarters is now recruiting for a full time man to dissimilate technical information. He also mentioned urgency of submitting Data Sheets to Mr. Chase in usable form.

A. W. Plummer mentioned the Question & Answer column in *Tappi*, and that H. L. Warner had been assigned the review thereof for project sources ideas. Mr. Warner plans to submit a report on this. E. H. Olmstead commented that committees are being requested to stimulate this column.

A. W. Plummer requested technical papers from members. The response so far has been very poor. A plan to hold each member responsible for obtaining one paper might be considered. S. W. McKibbins expressed some thoughts on chemical engineering papers and was requested to present these thoughts in a letter to the committee.

Nonmembers present were requested to take pledge forms for membership, if interested.

H. W. Hemphill of Singmaster & Breyer, Inc. commented on Singmaster & Breyer's program on nitric acid pulping. Feelings were expressed that pulp and paper might not be up to date on chemical engineering in other industries. Young, inquisitive chemical engineers might well advance revolutionary processing changes in the industry.

Many of those present had to leave at this point (about 1:45 p.m.) due to technical sessions following.

Mr. Plummer announced that Mr. Clemens, the secretary, had found it necessary to resign from the committee since his position with Dorr-Oliver now occupied him almost entirely outside of the pulp and paper industry.

Mr. Clemens expressed his regrets at having to take this step and extended his best wishes for the committee's future.

An informal discussion on our problems followed until about 2:00 p.m. when the meeting was adjourned.

R. F. Clemens, *Secretary*

Drying Committee

The meeting was called to order at 11:00 a.m., Nov. 30,

1960, at TAPPI Headquarters in New York by the Chairman John Verwayen. The minutes of the previous meeting were approved.

New members and guests were introduced.

The agenda for the Drying Committee meeting of Wednesday, Nov. 30, 1960, was as follows:

1. Assignment of tasks outlined in the minutes of the Jacksonville meeting.
2. Program for 1961—Suggestions for papers and speakers.
3. Coordinate High Velocity Drying Questionnaire with Steam and Power Committee.
4. Appointment of committee program chairman.
5. Establish on which day Drying Committee meeting should be held during 46th Annual Meeting in New York City.
6. Membership address list and mailing list.

The proposed list of projects for the Drying Committee for operation in the year 1961 has been mailed to all the committee members. These projects have been developed with the cooperation of the Engineering Division staff. The purpose of this meeting was to assign specific projects to the committee members that had interest in some of the projects.

From the list of proposed projects:

1. Development of a standard TAPPI method for obtaining the performance characteristics of high velocity air hoods and drying systems.

It was suggested that Mr. J. J. Killian be offered the chairmanship of this task group since he has wide experience in different types of high velocity air systems. Other members suggested for this task group were S. G. Holt, J. Means, L. Blomgren, and J. A. Villalobos.

2. A method for measuring the surface temperature of driers and drying webs.

L. R. Vianey volunteered to serve in this task group, also R. I. Cole.

3. Methods for measuring the moisture content (specific moisture relative humidity) of drying systems.

Committee members present at this meeting felt that this project was something that could be obtained directly from published information. Mr. Cirrito suggested the psychrometric charts by Zimmerman and Levine, which have information on the subject. Other standard textbooks have enough information on this area so that it will not be necessary for the Drying Committee to undertake any special project.

4. Development of a standard nomenclature for expressing moisture content or dryness, with some means of conversion for current terms.

Some work has already been done on this project and Dr. White presented some information pertaining to this project. Members of this task group are Dr. White, A Cirrito, D. Pohlman, and K. Khandelwal.

5. Information on thermo energy cost per pound of water removed at different moisture contents.

The native of this project should be clarified and the objectives spelled out. Dr. Holt was suggested as chairman and the Drying Committee chairman will contact Dr. Holt to this effect.

6. Extend "Methods for Moisture Sampling of Paper" to include press section sampling.

Mr. Pohlman was suggested as chairman of this project. Also, Mr. Asselin volunteered for this project.

7. Survey of high performance hood of paper machines and coaters. Suggest that data be presented as a curve of drying rate with high performance hood in terms of equivalent cylindrical driers versus moisture content for a certain furnish of coating.

The members of the committee felt that this project could be merged with project no. 5.

8. Survey of drying rates with low pressure driers to supplement Project 505 "Drying Rates with High Pressure Steam in Paper Machine Driers." A new method of presentation is suggested if possible to avoid the wide spread in data.

Les Janett, is at present working on this project. J. A. Villalobos was assigned to contact Mr. Janett on this subject and report to the committee on the progress of this project.

9. Effect of drier felt variables on drying rates. Quantities such as felt tension, moisture content, constructions, etc. to be investigated.

The work on this area has been done in the past by the Felt Drying Committee of PIMA. There is a possibility that the Drying Committee of PIMA will be transferred to TAPPI.

Mr. Villalobos is to contact Mr. Metcalfe, J. O. Ross Engineering, and report on the progress of this transfer.

10. General bibliography of drying.

11. Yearly review of significant articles and significant developments in drying.

These two projects will be consolidated since they are of the same nature. Mr. Khandelwal will contact The Institute of Paper Chemistry in Appleton, Wis., to discuss the possibilities of getting the information suggested in projects nos. 10 and 11.

12. Survey of exotic heating methods for drying purposes (high pressure water, hot oil, Dow therm, etc.).

Mr. Swaney volunteered for this task group. Mr. Hansen, J. O. Ross Engineering, is to be contacted to see if he would like to participate in this project.

13. A research program, perhaps under TAPPI sponsorship to cover:

A. The aerodynamic characteristics of high velocity types of drying systems.

B. Heat transfer characteristics of high velocity types of drying systems.

C. Mass transfer and diffusion in high performance drying systems.

The Drying Committee felt that this program could be integrated with project no. 1.

14. Comparison of coating drying and paper drying performance of various types of commercial drying equipment.

The members of this group would be Mr. Fink, Mr. Green, Mr. Asselin, and Mr. Lattimer, of Time and Life, Springdale Laboratories, is to be contacted to be asked to serve in this committee.

15. Paper defects due to drying (printing grades in particular).

The Drying Committee felt that this type of project was beyond the scope of the work of the committee. The nature of paper damage due to drying or other causes, is such a vast subject that it would be practically impossible to make any headway on this type of project.

Suggestions on Papers and Speakers

The possibilities for papers to be presented on the next Engineering Conference seem to be on the general subject of high velocity drying.

Mr. Villalobos suggested the possibility of a paper on high velocity drying by means of nozzles, to enlarge the knowledge of high velocity drying as presented in the last TAPPI conference. The nature and extent of the paper is not at this time well defined, but the possibilities of presenting such a paper are very good.

Also, in the same general area, the interest in the industry for knowledge in coating drying presents a possibility for a paper. People in the coating industry are to be contacted to find if there is a possibility of presenting a paper on the subject.

There are indications that other people in the industry have material to consolidate into a paper, and they will be contacted by Mr. Verwayen. These people are J. J. Killian, E. G. Drew, and J. Means.

Committee Program Chairman

The publicity chairman for the Drying Committee has not been appointed.

J. A. Villalobos, *Secretary*

Mechanical Engineering Committee

The Mechanical Engineering Committee met for luncheon on Monday, Oct. 24, 1960, at 12:30 p.m. in the Spanish Room at the Hotel Robert Meyer, Jacksonville, Fla. Chairman J. S. Mudgett presided. Fourteen members and six guests were present.

Chairman Mudgett called the meeting to order at 1:30 p.m. with appropriate remarks welcoming all members and guests, followed by self-introduction of all those present. The first order of business concerned the appointment of secretary of the Mechanical Engineering Committee. Chairman Mudgett appointed R. P. Finney, St. Regis Paper Co., to serve in this position.

It was unanimously agreed upon to have the secretary of the committee send a letter to our former secretary, J. C. Harper, expressing the group's best wishes for a rapid recovery from his recent illness. The Mechanical Engineering Committee Program to be presented Wednesday, October 26, was briefly outlined by Chairman Mudgett and should be exceedingly interesting to all in attendance.

Mechanical Engineering Committee

C. E. Hill reported briefly on the papers to be given and had a brief report on Data Sheets that are in process and will be available for publication in the near future.

1. Vacuum Factors for Paper Machines.
2. Recommended Standard Method for Measuring Vacuum.
3. Barometric Leg Design.

Looking ahead to the 1961 Engineering Meeting for subjects of papers to be given, considerable interest was indicated in a paper that would give a "Mill Man's Viewpoint" of the conversion or switch from the old type to the new type suction rolls. It was decided that a paper of this nature definitely warrants discussions and exploration at the February, 1961, meeting.

R. T. De Pan, chairman of the Pulp Preparation Subcommittee, was called upon to give a report of the progress of this committee. At present, there are no papers available. However, Ray requested at the meeting that if anyone had suggestions for subjects of papers, please state them, and the following list of subjects were presented:

1. Continuous digesters (comparison of types and makes). On this subject it was suggested that a panel discussion would be appropriate with mill men partcipating. Ray stated that he would do follow-up work on this subject.
2. Prescreening ahead of the washers with pressure screens.
3. Washing systems.
4. Bleaching systems.
5. Stock cleaning systems.
6. Stock refining.
7. Stock agitation.
8. Chest and tower design.
9. Comparison of types and makes of digester valves.

N. Shoumatoff of the Staff Advisory Committee was present at the meeting and was called upon by Chairman Mudgett to offer his and the staff's remarks. Mr. Shoumatoff asked the group if TAPPI engineering projects were being written up on Standard TAPPI forms which are available from TAPPI and are TAPPI project numbers being assigned?

It is anticipated that in the near future that all Data Sheets and projects concerning all divisions of TAPPI be assigned project numbers, and the standard forms used.

A. Winchester of TAPPI, New York, spoke to the group on data sheet activity pointing out the importance of accurate and uniform reports. The proposed funds that are to be established for engineering work on Data Sheet processing, the mechanics of filling out the Data Sheets and the assignment of numbers to the projects was covered with various questions asked by those present.

Chairman Mudgett reported on the Research Program for Vacuum Requirements for Paper Machines and stated that April 1st would be the deadline for the estimate of costs required for the project.

A committee of the following were appointed by Chairman Mudgett to assist in details: C. Hill, F. Taska, and J. Mudgett.

Reports of nonactive committees and subcommittees were issued as follows:

The Wood Preparation, and Finishing and Converting Subcommittees are at present without a chairman. A brief discussion on how and where to get personnel to serve on these committees was held and it was decided that possibly by the February 1961, meeting that these committee vacancies could be filled.

Chairman Mudgett stated in his closing remarks that the 1961 Engineering Meeting should contain four or five papers as in previous sessions. The TAPPI committee membership forms were passed out for signatures of those desiring to serve.

R. P. Finney, *Secretary*

Process Instrumentation Committee

The meeting was called to order by Chairman Powell on Oct. 27, 1960, at The Robert Meyer Hotel in Jacksvonville, Fla.

Data Sheets Subcommittee

Chairman Morrissey had the discussion of the proposed TAPPI Data Sheet-Instrumentation Flow Plan Symbols. The sheets were distributed to all present. Many comments were offered. Any comments for consideration are to be reported to Morrissey by letter before Jan. 1, 1961.

Project 775—Final Report

Bob Hurm reported that the work would be completed with presentation of his paper at this conference.

Project 692

Earl Prince reported that the survey would be in the mail by December 1, according to Herb Teeple.

Data Handling and Computer Control

Don Michel reported on contacts he had made. It was suggested that the Process Instrumentation Committee ask for 2 hr. on the 1961 conference program for a panel discussion on this subject, moderated by Don Michel. Possibility of other co-sponsors was suggested. Ed Thode was quite interested in this for his committee. Another one possibly interested would be the Process Dynamics Committee.

Proposed New Projects

Dick Gardner suggested two topics which were received by the committee with enthusiasm. These will be handled for Data Sheet preparation as follows:

1. "Material Selection for Instrument Air Piping," by H. E. Kirkland.
2. "Requirements for Instrument Air Supply Systems," by R. R. Gardner.

Other projects discussed:

3. "Economics of Instrumentation Installation," by C. W. Dawson as chairman and G. A. Charters Scope of this project is to be submitted to the committee chairman by the subcommittee.
4. Consistency project similar in scope to 775 on moisture.

TAPPI-ISA Joint Symposium Report

Report was given by Gar Eastwood who is General Symposium chairman. The symposium is to be held May 10–12, 1961, at the Northland Hotel in Green Bay, Wis. There will be no formal exhibits. A very ambitious and worth-while program was outlined by Gar. It includes: panel on installation and maintenance; management workshop; mill instrumentation education panel; computer panel; mill tours; and ladies' program.

1960 Conference

Jim Powell advised we were all set for the program to be presented later in the day.

1961 Program—Washington

Don Morrissey suggested papers previously discussed with Great Northern and Finch Pruyn & Co. Clarke will check with him. If needed, Dick Gardner also can put together a paper on Safety.

Papers were announced by Chairman Powell as:

1. "Controlling the Variables," by W. A. Wrase of S. D. Warren Co. Clarke is to determine more definite information on the content.
2. Paper by Herb Couture, East Texas Pulp & Paper Co., yet untitled, on a control system for auxiliary fuel in a chemical recovery unit. Clarke is to write Couture regarding stress of safety.
3. See suggestions above.
4. Final report Project No. 692, "Organization and Importance of the Paper Mill Instrument Department."

1962 Program—Montreal

Horace Fishwick has arranged for a paper by R. C. Cross of St. Regis Paper Co.

Chairman Powell requested that those members previously requested to procure papers for this conference (Conner, Pentecost, Harman, and Pearson) have an idea of the paper by the time of the interim meeting. We must have outlines prior to the 1961 conference.

Prospective New Members

Members are requested to submit names to Earl Prince. More mill people are needed. The list of members and their company supervisors was up-dated.

TAPPI's Questions & Answers

Members were requested to forward to the chairman or secretary applicable material for this column in *Tappi* magazine.

Interim Meeting

Next meeting is to be held about the time of the TAPPI-ISA Symposium, at that location, pending further arrangements.

Appreciation of the membership to Jim Powell for outstanding leadership over the past several years was extended.

The meeting was adjourned and Jim Powell turned over the chairmanship to Earl Prince. Gar Eastwood assumes the vice-chairmanship.

Sanitary Engineering Committee

The Sanitary Engineering Committee meeting, held at the Fifteenth Engineering Conference in the Robert Meyer Hotel, Jacksonville, Fla., was called to order at 2:00 p.m., Oct. 25, 1960.

Chairman Moggio briefly reviewed the papers to be presented at the Sanitary Engineering Session of the current conference. Three papers, all in keeping with the previously selected theme, were on the program:

"Industrial Water Conservation and Re-use," by R. D. Hoak of Mellon Institute.
"Water Treatment for Color Removal," by S. T. Powell and L. G. von Lossberg of S. T. Powell & Assocs.
"Some Methods of Waste Water Recovery for the Pulp and Paper Industry," by T. L. Moore of Gibbs & Hill, Inc.

Mr. Simpson reviewed progress on the Data Sheet "Unusual Methods of Measuring Flow," and pointed out that greater cooperation from members will be necessary if the Data Sheet is to be completed. Mr. Moggio suggested that since each committee member has probably worked with unusual or simple methods which he considers commonplace but which are generally unknown, the members should write up their own experiences. Mr. Simpson agreed to contact all committee members and ask them for data, bibliographies, and other pertinent material on methods of metering flow. Mr. Dembitz agreed to approach editors of technical magazines in New York City and enlist their aid in locating past articles on the subject. Mr. Owens said that if the committee wished to circularize TAPPI members for information on the subject, headquarters would cooperate by sending the committee's questionnaires to all members, to corporate members, or to "preferred" convention registration lists.

Next, it was suggested that a monograph be prepared describing sanitary treatment processes applicable to the pulp and paper industry. This suggestion was tabled until such time as the Data Sheet on measuring flows is nearer completion.

The preparation of an annual review of the literature covering pulp and paper mill effluent disposal and treatment, air pollution, and stream pollution—a review which had been proposed at a previous committee meeting—was discussed and approved. Mr. Moggio said he would ask Dr. Lardieri to direct this project, since Dr. Lardieri prepares a pulp and paper bibliography for the *Water Pollution Control Journal*. The committee project would include a list of available pertinent articles on water and air pollution applicable to the pulp and paper industry; abstracts of each article; and extended summaries of important articles. Mr. Owens promised that the bibliography could be printed annually in *Tappi* as a Sanitary Engineering Committee project. It was decided to ask each committee member to assume responsibility for several magazines, listing and abstracting all suitable articles in those magazines. To this end, Mr. Dembitz will make a list of all major magazines which might carry such articles and will distribute the list to committee members with a request to check those magazines they regularly read. Mr. Moggio will then assign the responsibilities.

It was agreed that the Sanitary Engineering Committee will not sponsor a session at the February annual meeting in New York City.

Discussion was next held on a theme for the Sanitary Engineering Session for the Sixteenth Engineering Conference to be held next October in Washington, D. C. Three themes were broached.

1. Air pollution.
2. Discussion of hypothetical problems.
3. Case histories of actual installations.

It was agreed to build the program around case histories. It is planned to devote each paper to the problem of one mill and how that problem was solved. If possible each paper will illustrate a different type of treatment, e.g., aerated lagoons, activated sludge, biooxidation towers. Mr. Weston suggested that it might be possible to obtain enough papers for two sessions, and in any event, that the program be concluded with a panel discussion of the papers presented. Mr. Moggio will handle arrangements for the papers. Committee members will be asked to send him the names of mills with treatment plants together with the name of the person to ask about presentation of a paper.

Finally, a discussion was held on the committee membership. There was complete agreement that the membership must be expanded to achieve the outlined goals, and that it is important to obtain greater participation by industry. Committee members are therefore requested to write Mr. Moggio with suggestions for new members. In addition, the committee plans to initiate a survey of corporate members. They will be asked for the names of men assigned to sanitary work; how much time the men devote to such work; what the men's background is; and which man could be asked to serve on the committee. Because of the delicate nature of pollution control information, it will be emphasized that any answers submitted will be held in strictest confidence.

A. E. Dembitz, *Secretary*

Steam and Power Committee

Activities of the Steam and Power Committee, during

TAPPI's Fifteenth Engineering Conference at the Robert Meyer Hotel, included:

1. A 3-hr. technical session as listed in meeting program.
2. A special extra, 1-hr. session on the "Interaction of Water and Smelt."
3. A committee luncheon with subcommittee status reports and discussion.
4. Authors' breakfast.
5. Two meetings of the Steering Committee.
6. Meetings of several subcommittees to work out details of their activities.

Technical Session

H. R. Emery was chairman of our main session held in the Windsor North Room, 9:00 a.m. to 12 noon on Thursday, Oct. 27, 1960. Attendance during the "papers" portion of the session ranged up to about 140 people. The papers were:

1. "Water Treatment for Boilers Operating in the 600–1250 lb. Range with High Make-up," by L. Limon, Graver Water Conditioning, and R. A. Dando, St. Regis Paper Co.
2. "Why the Power Department Should Supervise the Operation of Recovery Boilers," by H. R. Arnold, Continental Can Co.

T. F. Woodward, Scott Paper Co., was moderator of the panel discussion on "Training of Power Plant Personnel." Attendance for the panel ranged up to about 90 people and the panel members were:

M. S. Ginter, Dow Chemical Co., Midland, Mich.
W. S. Tierney, Detroit Edison Co., Detroit, Mich.
J. W. Herrington, Buckeye Cellulose Co., Foley, Fla.

All papers and panel discussions were preprinted by TAPPI for distribution at the 15th Engineering Conference and are being published in this issue of *Tappi* (March, 1961).

The value of this session was greatly enhanced by the lively audience discussion that followed the excellent formal presentations.

Special Session

An extra committee sponsored session scheduled for 2:00 p.m. on October 24 was announced during the conference's opening session.

More than 100 people attended this timely session where a research type, sound movie on the "Interaction of Water and Smelt" was shown. This film showed the violent reactions that can occur when various types of smelt, liquor, and water are intermixed. The Steam and Power Committee has a subcommittee on "Recovery Boiler Operation" and this session was considered very timely because of the current interest in the problems associated with recovery boiler operation. The film documented the results of some tests conducted by the Babcock and Wilcox Co. It was introduced and discussed by C. T. Smith and C. E. Rogers of the Babcock and Wilcox Co.

Committee Luncheon

A total of 39 attended the Steam and Power Committee's luncheon on Oct. 26, 1960. This included 27 of our 36 committee members, three TAPPI Staff and Engineering Division officers, and 9 guests.

Agenda for this luncheon meeting included:

1. General informative presentations and suggestions by TAPPI Staff and Engineering Division officers.
2. Introduction of new members of the committee.
3. Interim reports on activities of our subcommittees.
4. Report on program for 1961 Engineering Conference.
5. Report on program plans for 1962 Engineering Conference.
6. Agreement on time and place for spring committee meeting.

General

Vince Owens announced that John Warner had recently passed away. Mr. Warner was the first chairman of TAPPI Engineering's Steam and Power Committee and had maintained an active interest in our activities over the years.

Technical Information. W. C. Bloomquist, Secretary of TAPPI's Staff Advisory Committee, reported on TAPPI's plan to increase the effectiveness of providing specialized industry technical data to TAPPI membership. To implement the program, TAPPI will hire a competent engineer to provide full time, professional leadership to the program. His responsibilities will include a review of technical data proposed by various committees in the different divisions of TAPPI, edit and verify this information, and see that it is published in an easily used form. Equally important is his assignment to review technical information after it is published to be sure it does not become obsolete. This assistance from TAPPI Headquarters should be of great assistance to the committees whose ability to publish needed technical data has been limited by the detailed work required to establish format and present available data in the final form required for publication. The term "Data Sheet" will be replaced with "Technical Information" which more accurately describes the material.

Important Engineering Concepts. Both Mr. Bloomquist and Mr. Osborne cited the constructive suggestions made in a letter to Mr. Osborne from Paul C. Baldwin, vice-presdient of Scott Paper Co. This letter will be found on pages 170A and 171A of the September 1960, issue of *Tappi*.

Mr. Bloomquist reiterated the importance of engineers giving their management alternate solutions with concrete suggestions. To do this, engineers must be knowledgeable in the various facets of investment, operating costs, income tax, and other related items. We can't divorce steam and power activities from economics, and Mr. Bloomquist recommended that we be represented on the Economics Committee.

Committee Membership. Steam and Power Committee membership now totals 36 including eight who have joined since our Committee meeting in March, 1960. Mr. Emery introduced new members and assigned them to various subcommittees so they could start contributing to the committee's work immediately.

Subcommittee Reports

A report of subcommittee activities, including subcommittee objectives are summarized here.

Subcommittees that have been assigned "Project Numbers" in the past will now have "Committee Assignment Numbers" instead.

Annual Listing of Power Plant Equipment in Industry (CAN 681). Objective: Annual compilation of power plant equipment supplied to the pulp and paper industry. Henry Wallace reported that he had been in contact with H. O. Teeple at TAPPI Headquarters and data would be compiled from questionnaires now being mailed from TAPPI. This information is to be published in *Tappi*.

Steam and Power Consumption (CAN 683). Objective: Establish data on steam and power consumption in various phases of pulp and paper production. John Hoad reported that his subcommittee's questionnaire had been sent to selected mills, suppliers, and consultants and their constructive comments and criticisms received.

Before the spring committee meeting, it is expected that questionnaire forms will be revised and modified to incorporate suggestions received. Questionnaires will also be set up so applicable questions can be pulled out for mailing to specific mills so a straight kraft mill does not get a lot of questions on groundwood, etc.

At time of spring meeting, Hoad will announce type of mill selected for coverage in next year's program.

Hoad announced that data received would be analyzed and put in shape so mills can see maximum, minimum, and average use of steam, kilowatts, and other items for specific types of mills.

Bloomquist suggested rather detailed data needed to make information most useful.

Mr. Hoad must formulate rather definite ideas of how the final information is to be presented and be sure that answers to questionnaires will provide the detailed information needed.

Bloomquist also suggested a look at some technical information that the Drying Committee has prepared to see if any of this is appliable to our study.

Technical Information (CAN 684). Objective: To review existing and provide new Technical Information Shuts applicable to steam and power problems in pulp and paper industry. Percy Nelson reported that he now has 21 sheets of Technical Information on piping ready for review. This information covers piping from 50 to 2500 p.s.i.g.

Nelson expects comments from the reviewers so information can be revised and ready for publication by March, 1961.

Osborne and Bloomquist reiterated that key to publication in TAPPI's Technical Information series is to include data not been published elsewhere.

Progress in Nuclear Power (CAN 726). Objective: To keep committee informed of nuclear developments affecting the application of nuclear energy for industrial steam and/or power generation. George Gregg announced that his subcommittee will have a report for distribution to committee members at the time of our spring meeting. He commented on several nuclear installations now going in service and others that are being constructed.

Question and Answer. Objective: To provide *Tappi* magazine sufficient technical material so a continuing "Question-and-Answer Section" can be maintained under the TAPPI Engineering Division masthead. Milton Ellis announced that one set of questions and answers had already been sent to *Tappi*. A second set is now in shape and he expects to follow with four or five Q & A's each month. He appealed to the committee members for help in answering questions that have been submitted as well as to send in their own questions or questions and answers.

Program. Objective: To communicate with those participating in Steam & Power Committee sponsored programs so papers of optimum quality are prepared and presented to meet the time schedules established by TAPPI. Charles Podas commended the authors and panel members for their fine contribution to the 15th Engineering Conference. He also suggested that the committee propose preprinted papers again for the 1961 Engineering Conference.

Vince Owens suggests that the Steam and Power Committee may want to consider two 3-hr. sessions at each Engineering Conference. He notes that several committees in the Engineering Division are already sponsoring two sessions. He encourages our committee to do everything possible to give company management reason to send their steam and power people to TAPPI's Engineering Conferences.

The Steam and Power Committee never wants to sacrifice quality for quantity. But with an active membership, enough manpower may now be available to develop additional papers. This subject will be aired during the spring committee meeting and consideration be given to a second session for the 1962 Conference.

New Developments and Their Effect on Steam and Power Systems (CAN 854). Objective: To review and report on new developments as they affect the mills Steam and Power System. This subcommittee, formed in March, 1960, is off to a good start under the leadership of Charlie Bush. Mr. Bush announced that he has work for new members on their 1960–61 Committee assignment which is "High Velocity Air Driers." Sufficient data have not yet been received and checked for accuracy to present in an interim report. He expects to have final report for the March, 1961, meeting.

It was announced that Woody Holt of the Drying Committee would like to have one of his committee members also be an active Steam and Power Committee member.

Recovery Boiler Operation (CAN 853). Objective: To study and report on the safe and economical operation of Recovery Boilers. John Hoeft announced that great interest has developed in his subcommittee because of the recent troubles with recovery boiler operations. The subcommittee was formed in March, 1960.

The subcommittee will study data available from manufacturers and insurance carriers to determine just how TAPPI can make the greatest contribution. Mr. Hoeft is also anxious to break his subcommittee's work into manageable 1-yr. assignments which can be completed and reported on. At the present time, indications are that 80% of furnace explosions are attributable to auxiliary fuel explosions.

This subcommittee will sponsor a panel for the 1961 engineering conference. Mr. Emery will work with Mr. Hoeft in finalizing details of this panel on recovery boilers.

Membership. Objective: To seek out qualified and interested personnel and recommend them for membership in the committee. Successful is the most descriptive word for operation of the Membership Subcommittee during the first 6 months of its life. Nick Mailhos reported that, through the efforts of his subcommittee, eight new, experienced and competent members have been recruited for the Steam and Power Committee. Subcommittee programs must keep pace with our membership so we can never be accused of having members with nothing to do. New members are not being solicited at the present time.

The various subcommittees must be alert to the need for new members, either to handle new work or to replace existing members who, because of changed business interests or other causes, are not actively participating in the work assigned.

Training Power Plant Engineers (CAN 682). Objective-Document suggested methods of training power plant personnel. The panel session on training summarized much of the information Tom Woodward has developed in his subcommittee. Tom had prepared additional information and distributed it to all committee members prior to Jacksonville Meeting. It is hoped that this subcommittee's recommendations for final reporting can be accepted at our March, 1961, meeting. This subcommittee will then be disbanded.

1961 Program

Subjects and authors have been established for the "papers" portion of the committee's session at the 1961 Engineering conference. This sixteenth TAPPI Engineering Conference is scheduled for the Shoreham Hotel in Washington, D. C., on Oct. 15–19, 1961.

A panel on "recovery boilers" is scheduled to complete the Steam and Power Session. It is expected exact subject and panel members will be finalized at the time of our March, 1961 Committee meeting.

The papers and authors that have already been established are:

"Centralized Control of Steam and Electric Power in the Pulp and Paper Mill," by R. E. Crossley, Great Northern Paper Co.

"Economics of Operating One 20,000-kw. Turbine-Generator versus Two 10,000-kw. Units Taking into Consideration Reduction of Production During Unit Inspections," by T. J. Judge, International Paper Co.

Tentative subject of the Panel Discussion is: "Recovery Boilers—Costs to Industry and Auxiliary Fuel Developments."

1962 Program

The committee was polled early last fall for suggested topics for the committee's program at TAPPI's Seventeenth Engineering Conference. Mr. Emery also asked those attending our committee luncheon to take a few moments to suggest topics of interest to them. The group responded with several good suggestions—some for general subcommittee assignment, some for papers and talks, and other general suggestions for committee consideration. These suggestions, plus those received earlier, are summarized and will be distributed to all

Steam and Power Committee members for our first balloting on topics for the 1962 conference.

Authors Breakfast

All participants in our Jacksonville session met for breakfast prior to the program on Thursday morning, Oct. 27, 1960. Even though we hope that all details have been taken care of much before the day of the sessions, for many years the Steam and Power Committee has scheduled an authors breakfast to be doubly sure the session chairman and the authors have a clear understanding of the facilities that will be available.

Steering Committee

The Steering Committee had two meetings prior to our Committee luncheon to work out agenda and proposals for considerations by the overall committee.

Subcommittee Meetings

Most subcommittees took advantage of having their members together in Jacksonville and held one or more meetings. These interim meetings greatly increase the effectiveness with which subcommittees carry on their assigned work. It is expected that some will schedule subcommittee meetings in Chicago in March, if not before.

W. B. Wilson, *Secretary*

Pulp Manufacture Division

Mechanical Pulping Committee

The meeting which was held at the John Marshall Hotel, Richmond, Va., on Dec. 8, 1960, was opened with a request by the chairman, Mr. Parsons, that the secretary read the minutes of the last meeting of Sept. 23, 1960. They were accepted as read, except that it was noted that John White has the new title of vice-chairman, Paper Manufacturing Division, rather than as stated.

Project No. 680—A Survey of Groundwood Mill Process Instrumentation (J. K. Kirkpatrick, chairman). J. K. Kirkpatrick notified Mr. Parsons by letter that the questionnaire had not been mailed as yet to TAPPI for printing and circulation but he expected to do so within a few days.

Project No. 932—Annotated Bibliography for Year (Gil Godin, chairman). Mr. Godin has prepared a very complete report and summary. The report includes inventions as well as literary items extending from December, 1950, to Nov. 1, 1960. Mr. Godin inquired as to the form in which the bibliography should be submitted. He was directed to correspond with R. P. Whitney of The Institute of Paper Chemistry so that there would be no conflict as to the form in which it should be compiled. (See this issue of *Tappi*.)

It was decided that this project should run annually from November 1 to November 1, and also that it be assigned a new project number each year.

Project No. 793—Fourth International Mechanical Pulping Conference, 1961. Mr. Parsons, who is general program chairman of the forthcoming International Conference, reported that he had received promises of ten excellent and timely technical papers, with prospects of more. He solicited the help of the committee in developing a worth-while program and as a result considerable discussion ensued regarding the weight of the papers, titling, arrangement of program, program publicity, etc. The relative merits of panel discussions with group leaders versus formal papers and question-and-answer periods were exhaustively discussed. The conclusions reached were that the program format of the Third International Conference was most effective and that it would be followed with minor modifications for the Fourth International Conference.

Project No. 925—Better Methods of Mechanical Pulp Evaluation (A. A. Yankowski, chairman). No report at this time except that the subcommittee is studying the project.

Reports of Subcommittees

a. Grinder Development. No report.

b. Mechanical pulp by other means that grinding on a pulpstone. No report.

Membership

Mr. Parsons and the committee officially welcomed Jim Griffin of the Great Northern Paper Co. to active membership. Mr. Parsons, in his remarks, noted that Mr. Griffin had already made a number of constructive contributions to our deliberations.

A letter from J. H. Heuer, vice-president of manufacturing, Great Northern Paper Co. was read, in which he stated approval of Mr. Griffin's service with our committee and he also stated that every effort would be made to afford him the opportunity of attending meetings. Mr. Heuer was especially pleased that an operating superintendent had been selected.

Piero Bersano, Cartiere Burgo Co. of Italy, cabled that he was unable to attend the meeting and he extended his best wishes for a successful meeting.

Christian Anker, Aktieselskapet Risor Traemassefabriker, Risor, Norway, also cabled as follows:

> Very much regret unable attend Stop Please inform committee grinder 5 burred last time October 24 and has since made 2480 short airdry tons in 1052 hr. Stop Grinder 4 likewise November third 2040 tons 830 hr. Stop Average load now 2500 kw. on both and 1030 kw-hr. per ton Stop Original faint trace of burr long since disappeared also due to steelbrush used in all 13 times Stop Quality as usual with exceptional high long fiber percentage Stop Stones 60 single grit congratulations excellent Norton performance and regards
>
> Christian Anker

Gil Godin of the Johns-Manville Research Center attended as alternate to E. M. Jenkins. Mr. Parsons commended Mr. Godin for the fine contributions he is making to committee activities.

A letter of resignation from J. J. Perot was read in which it was stated that Mr. Perot was unable, conscientiously, to fulfill his duties and that he was reluctantly forced to make this decision. His resignation was regretfully accepted.

New Business

A motion was introduced by M. S. Anderson that the so-called designation, "pitless grinding," be called "the Anker technique of pulp grinding." This motion was seconded and carried by acclamation. It was decided that this recognition was due Mr. Anker because he had the courage of his convictions and has pursued them to successful conclusions. The Anker technique as presently practiced consists of running pulpstones without a pit and at speeds higher than normal. His telegram explains in part what he has accomplished to date.

Future Meetings with Suppliers' Representatives

This matter was referred to the second vice-chairman. He will be instructed to arrange to have suppliers' representatives as guest speakers on occasion.

It was suggested that a meeting be held with and at the same time and place as the CPPA Mechanical Pulping Committee, to discuss the Fourth International Conference. Mr. Parsons will write to J. K. Kirkpatrick, liaison officer requesting that arrangements be made.

Some time was devoted to the discussion of mill problems but as there were no conclusions there will be no further comments at this time. However, time will be allotted at all future meetings for discussions of mill problems, and it was requested by the chairman that members attending meetings be prepared on this subject.

Mr. Parsons reminded the committee that he had requested members to drop a note to T. F. LaHaise as outlined in para-

graph 5 on page 8 of the minutes of the September 15 meeting. Mr. Parsons extended the thanks of the committee to the Johns-Manville Corp. for the invitation to visit their modern insulating board plant at Jarrett, Va. Some members afforded themselves the opportunity to visit this plant on the day following the meeting.

J. H. Perry, *Secretary*

Testing Division

Release Paper Testing Committee

The initial meeting of the newly formed Testing Division Release Paper Testing Committee was held on Dec. 20, 1960, at TAPPI Headquarters. Peters Thomas introduced himself as chairman of the committee and requested that each member introduce himself, identifying his company association.

The following members of the group were nominated as officers of the committee: Lester H. Reinke—vice-chairman; Albert A. Goodrow—secretary.

The two nominations above were seconded and approved by a voice vote.

The first consideration established by the committee was that of defining the scope of the activities to be undertaken.

A discussion, participated in by all present, was held next and the following definition was voted by the committee as the one which we will employ:

> "The scope of the Release Paper Testing Committee includes the study, development, standardization, and revision of analytical and physical testing methods for determining the physical properties and characteristics of release papers and paper board. The activities cover quality control, end use, and research and development phases of release paper and paperboard."

At this point in the meeting, Mr. Delforge requested information on a release paper for use in frozen food packaging. Mr. Chadderdon volunteered the assistance of his company.

Mr. Thomas next read a letter from Myron P. Marrander of Fiberboard Paper Products which evidenced his needs for a procedure for checking the quality of a silicone coating immediately off the machine. Mr. Marrander described a test in which the Johnson and Johnson tape is applied to the release paper at 100 p.s.i. for 2 min. He has found good reproducibility of results by using this method. Mr. Marrander also expressed a desire for a more reliable test for degree of cure of silicone coatings. Mr. Thomas has a copy of this letter for those interested.

The reading of Mr. Marrander's letter precipitated a general discussion of the needs of the converter and the consumer of release coated products.

For the purpose of brevity, some of the ore significant comments are listed below:

Mr. Howard: The testing procedure should not be limited to silicone coatings only. Other release coatings should fall within the scope of the test(s). It may be necessary to have more than one test because of the wide range of release materials and the variety of masses to be released from.

The group was in general agreement on both of Mr. Howard's comments.

R. M. Potts: Both Mr. Potts and Mr. McManus expressed a desire to have available a testing procedure to predict the performance of a release coating prior to actually establishing the coating as a standard product. They both felt that a converter's guarantee of a certain gram release was not an indication of the usefulness of the coating against their particular mass.

A. A. Goodrow: In reply to Mr. Potts' statement, Mr. Goodrow indicated his company's experience with the consumer in this respect. His company feels that the Keil test is merely a tool to distinguish the quality between different release coatings. Due to the wide variety of masses against which the sheet may be put, it is necessary, at present, to establish by use alone the efficiency of a particular release coating. Whenever possible, a sample of the mass to be released from is used as a point of reference to establish which coating has the greater chance of success but the burden of proof rests with the user of the silicone or other release coated substrates. To establish a testing method to accurately predict the usefulness of a release coated paper or board would appear to be a very difficult if not an impossible task.

H. J. Leavitt: Mr. Leavitt agreed with Mr. Goodrow's statement and added that in his opinion the testing procedure(s) which the committee should consider lie in three use categories: (1) production quality control (2) R & D tool to distinguish between types of coating, (3) if at all possible, tests to establish the efficiency of release coatings against some of the more common masses which require this type of product.

At this point in the proceedings, Mr. Burnston suggested that a member of the Release Paper Testing Committee be represented on the TAPPI Routine Control Methods Committee. The purpose of representation in this group is to see that when method(s) are developed by the committee they are published and established as standard by the Routine Control Methods Committee.

Peter J. Hakim volunteered for this assignment and his nomination was seconded and approved by a voice vote.

Mr. Thomas requested that a discussion of the Dow Corning RC-283 method for examining the quality of release coatings be placed before the committee for open discussion.

R. M. Kennedy described briefly his experience with the effect of the angle of peel on the release quality of silicone coatings by means of the Keil test. Mr. Kennedy is of the opinion that a 90° peel is more accurate than the 180° peel currently used. His reasons were based on the fact that using the 180° peel the degree of stiffness of the coated substrate interferes with the reproducibility of the test. Mr. Kennedy felt that a study of the merits of each angle of peel should be included in the committee's activities.

Mr. Thomas agreed and suggested that Mr. Kennedy establish a subcommittee to study this effect. Mr. Kennedy agreed to assume this duty.

Mr. Potts described his experience with the effect of surface smoothness on the adhesion of tape to a release coated sheet. His testing indicated that maximum adhesion and better reproducibility of results was obtained with a mirror finish on the adhesive as opposed to the relatively rough surface of the present Johnson and Johnson tape.

Discussion was next centered upon the need for a better adhesive tape than the Johnson and Johnson 5142.

Mr. Potts and Mr. Huddleston stated that their experience has been that the various rubbers employed in the manufacture of adhesive tapes and the variation in surface wetting power of one mass versus another has led them to believe that more than one tape may be necessary as a standard for testing release quality.

Mr. Thomas suggested that Mr. Potts and Mr. Huddleston join with Mr. Kennedy as a subcommittee to establish a standard tape or tapes. Mr. Potts and Mr. Huddleston agreed and were so appointed.

Mr. Burnston expressed his dissatisfaction with units used in expressing a Keil release value. He suggested that we keep the units expressed in the metric system. Rather than grams per inch, Mr. Burnston suggested that grams per millimeter or centimeter be used to conform with other established testing standards. This was agreed upon by the committee.

There was a brief discussion by Mr. Hakim of the reproducibility of results with the Keil tester or any other piece of equipment presently used.

Mr. Leavitt commented that the spring scale used on this equipment is subject to permanent stretch and therefore, reproducibility may be effected.

The committee agreed that a study should be undertaken to determine whether the Keil tester is adequate.

Mr. Leavitt commented, in addition, that neither the Dow Corning nor General Electric test methods indicated a definite waiting period prior to testing release quality. It is important to wait a definite period of time before testing to compensate for additional curing which may occur. This is a consideration which the committee should study.

Mr. Waddell felt that we should not limit ourselves to a standard adhesive to measure release. Perhaps another mass or medium should be considered. Mr. Waddell has further observed a difference in release with different speeds of peel. The 12 in. per min. peel seems to be much slower than the consumer would strip the release coated sheet from his product.

This meeting was adjourned at this point for lunch.

The afternoon session was begun at 2:25 with a discussion of the General Electric test method.

The merits of a standard metal plate, either stainless steel or aluminum, for the subsequent adhesion test were discussed.

Mr. Kennedy volunteered that he was in favor of the UUP-31B Federal Specification which illustrates a standard government testing procedure for adhesion of pressure sensitive tapes. This procedure employs a $5 \times 2 \times {}^{1}/_{16}$ stainless steel plate polished to a no. 4 finish.

Mr. Kennedy was asked by Mr. Thomas to consider this test in his subcommittee activities.

Mr. Waddell noted that the rubber roller presently used in both testing procedures (durometer 50) was not as efficient in effecting good contact between the tape and the release coated surface. Mr. Waddell suggested the use of a steel roller.

The feeling of the group on Mr. Waddell's comment was that good contact with an unaged sample of release paper is difficult to obtain because of the efficiency of the release coating itself and that rolling the tape after applying to the release sheet did not accomplish anything significant. We may be able to take advantage of Mr. Waddell's suggestion when carrying out the subsequent adhesion test.

At this point in the meeting, Mr. Thomas requested individual comments from each of the committee members on what they felt should be the primary considerations for the group prior to the next scheduled meeting.

As a result of this discussion, the following schedule for the next meeting was established:

1. Mr. Kennedy to report on progress of his investigation of a source for an improved testing tape or tapes. R. M. Potts and J. G. Huddleston are to provide Mr. Kennedy with samples of tape which they consider as being suitable for control testing of release coatings.

2. Mr. Kennedy to collect his data on the effect on release value of peeling at 180 versus 90°.

3. Mr. Kennedy to inform the committee of his opinions of the usefulness of the Federal specification on testing of pressure sensitive tapes UUP-31-B.

4. Mr. Howard to report on his progress in collecting a bibliography on releasing media including silicones, Quilon, and others.

5. Mr. Chiang to act as liaison man with L. W. Dickard of Fasson Products with attention to the new monograph being prepared on testing of pressure sensitive adhesives.

The next meeting of the Release Paper Testing Committee will be held on Tuesday, Feb. 21, 1961, from 9:00 a.m. to 12:00 a.m. in room 1036 at the Hotel Commodore in New York.

It is planned that this committee will meet twice annually.

Mr. Thomas closed the meeting by expressing his appreciation for the fine spirit of cooperation and enthusiasm which the group manifested.

ALBERT A. GOODROW, *Secretary*

Routine Control Methods Committee

The meeting of the Routine Control Methods Committee was held at the Eleventh Testing Conference at the Pantlind Hotel, Grand Rapids, Mich. It was called to order at 12:30 p.m. on September 27 by the chairman, J. R. Gunning. Mr. Gunning welcomed all committee men and those visitors who were just sitting in on the meeting. He then announced that due to a change of emphasis in his duties with his own company he had to give up the chairmanship of the committee. He thanked all the members for their cooperation and help during his term of office and then introduced L. J. Slentz, vice-chairman, who will be taking over the chair.

Mr. Slentz thanked Mr. Gunning for the introduction and expressed the appreciation of the committee for the work he had done in the past several years. He indicated his willingness to assume the responsibility of the position and promised that he would work to the best of his ability. He asked for the cooperation of the members.

The first report was from M. A. Burnston, technical associate of TAPPI, who is the liaison between the R. C. Committee and National TAPPI Headquarters. Mr. Burnston gave a complete rundown of all the methods published this year to date in *Tappi*.

Mr. Slentz then called for volunteers for the vice-chairmanship which position carries with it a chairmanship of the editorial board. Since none of those present volunteered, a committee of two, namely Gunning and Burnston, were left to review the membership and talk to any likely candidates and advise Mr. Slentz. At this time Mr. Gunning suggested that the division chairman and Noel Obenshain might like to say a few words on behalf of the National organization. Mr. Obenshain thanked the committee for the showing they have made during the past year and urged a continuation of the good work.

The methods on hand were then reviewed and those which have not received a project number were given one at this time.

Testing Division Assignments

The following is a list of test procedures assigned to the various committees of the Testing Division. The assignments or projects cover proposed Standards and Suggested Methods or revision of existing methods. The major assignment number should be used for reference. If anyone is interested in any of these methods please address your comments to the chairman of the specific committee.

ADHESIVES TESTING COMMITTEE—*Chairman*, R. C. BROWN

713 Monograph on Testing of Adhesives

CHEMICAL METHODS COMMITTEE—*Chairman*, W. K. WILSON

501 Revision of T 211 m-54, Ash in Pulp
550 Revision of T 600 m-45, Analysis of Formaldehyde
551 Revision of T 605 m-44, Sampling and Analysis of Coal
552 Revision of T 606 m-45, Preparation of Liquid Analytical Reagents
553 Revision of T 607 m-44, Analysis of Casein
554 Revision of T 608 m-42, Calibration of Volumetric Glassware and Analytical Weights
556 Revision of T 610 m-42, Preparation and Standardization of Volumetric Solutions
557 Revision of T 612 m-44, Analysis of Soda Ash
558 Revision of T 613 m-44, Analysis of Sodium Hydroxide
559 Revision of T 614 m-44, Analysis of Alum
560 Revision of T 617 m-44, Analysis of Lime
563 Quantitative Chromatographic Methods for Pentosans and Hexosans
777 Quantitative Determination of Tin in Pulp and Paper
778 Revision of T 601 m-46, Analysis of Gasoline
801 Analysis of Water Extracts
856 Intrinsic Viscosity of Cellulose

CONTAINER TESTING COMMITTEE—*Chairman*, A. W. HOFFMAN

689 Flat Crush Test of Corrugated Container Board
690 Compression Test of Fiberboard Shipping Containers

691 Bursting Test of Paperboard and Paperboard Products
716 Definition of Terms Relating to Shipping Containers
717 Revision of T 800 m-50, Revolving Hexagonal Drum Test
718 Revision of T 802 m-44, Drop Test for Fiberboard Shipping Containers

FIBROUS RAW MATERIALS COMMITTEE—*Chairman,* E. R. SCHAFER

351 Project Grant No. 43, revision of T 8 sm-40, Species Identification of Wood and Wood Fibers
502 Project Grant No. 94, revision of T 14 m-47, Dirt in Wood Chips

FILLERS AND PIGMENTS TESTING COMMITTEE—*Chairman,* W. R. WILLETS

699 Analysis of Calcium Carbonate
700 Analysis of Talc
701 Analysis of Diatomaceous Earth
702 Analysis of Calcium Silicates and Other Synthetic Colloidal Fillers
703 New Methods of Testing Fillers and Pigments
704 Correlation of Test Methods for Various White Fillers and Pigments
738 Analysis of Colored Pigments

MICROSCOPY COMMITTEE—*Chairman,* I. H. ISENBERG

577 Methods for the Identification of Printing
771 Revision of Test Method T 10 m-57, Species of Identification of Nonwoody Fibers

OPTICAL METHODS COMMITTEE—*Chairman,* R. S. HUNTER

321 Project Grant No. 125, Standardization of 75° Gloss Test Method T 480 m
566 Preparation of Test for Chapman Smoothness
795 Review of Brightness Methods T 217 and T 452
8002 Apparatus for Photomicrographs of Paperboard Surfaces under Tangent Illumination
8003 Optical Method for Ink-Setting Time
8004 Optical Method for Ink Show Through

PACKAGING MATERIALS TESTING COMMITTEE—*Chairman,* C. M. WOODCOCK

328 Flavor and Odor Transfer, Review of T 483
357 Water Vapor Permeability of Completed Package, at Various Temperatures and Humidities, with and without Rough Handling
387 Water Vapor Permeability at 100°F. and 90% R.H.
388 Insect Resistance, review of T 473
513 Revision of T 465 sm-52, Creasing of Paper for Water Vapor Permeability Tests
514 Gas Permeability of Sheet Materials

PAPER TESTING COMMITTEE—*Chairman,* W. P. DOHNE

451 Revision of T 411 m-44, Thickness and Density of Paper
477 Wax Test for Surface Strength of Paper
478 Water Resistance of Paper, T 433
480 Turpentine Test for Grease Resistance, T 454
540 Revision of T 432 m-45, Water Absorption of Bibulous Paper
541 Revision of T 461 m-48, Flammability of Treated Paper and Paperboard
542 Revision of T 410 m-45, Basis Weight of Paper and Paperboard
543 Revision of T 404 m-50, Tensile Breaking Strength of Paper and Paperboard
544 Revision of T 460 m-49, Air Resistance of Paper
545 Revision of T 403 m-53, Bursting Strength of Paper
766 Quantitative Determination of Mineral Fillers and Coating Materials

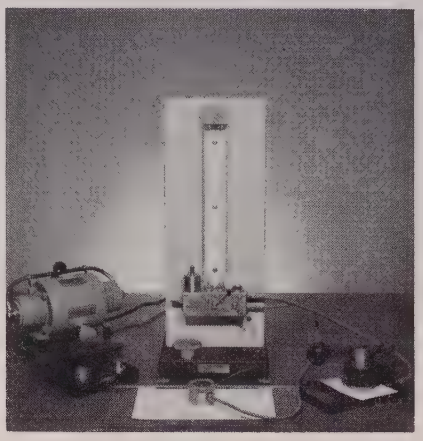
PAPERBOARD TESTING COMMITTEE—*Chairman,* W. O. KROESCHELL

612 Internal Tearing Resistance of Paperboard
717 Project Grant No. 167. Smoothness and Compressibility as Relating to Printability
711 Stiffness Testing Procedure for Paperboard, Review of T 441 m-48
712 Bursting Strength Test Procedure for Paperboard
895 Scoring of Paperboard
905 Measuring Force to Break Score

PAPER SHIPPING SACK TESTING COMMITTEE—*Chairman,* M. L. TAYLOR

605 Smoothness of Paper Under 3 p.s.i. Clamping Pressure
607 Procedure for Dry Tensile Testing of Shipping Sack Papers

THE
BENDTSEN TESTER
ONE LIGHTWEIGHT MACHINE THAT TESTS
PAPER & PAPERBOARD
for
SMOOTHNESS . . . POROSITY . . . HARDNESS
Instantaneously



INSTANTANEOUS: No waiting—No scale adjustments.
ACCURATE: No oil or dust can enter instrument. Smoothness not effected by porosity.
VERSATILE: Completely self contained, portable, no special training required. Tests smoothness, porosity & printing hardness of paper & paperboard. Accessories available for paperboard & Hardboard.

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608 Procedure for Wet Tensile Strength Testing of Wet-Strength Shipping Sack Papers
769 Tensile Energy Absorption of Paper
770A Measurement of Coefficient of Friction of Shipping Sack Kraft

PHYSICAL METHODS COMMITTEE—*Chairman,* R. E. GREEN

846 Revision of T 447, Moisture Expansivity of Paper
848 Dirt in Pulp, Revision of T 213
849 Internal Tearing Resistance of Paper, revision of T 414
850 Laboratory Processing of Pulp Beater Method, revision of T 200.
855 Softness of Sanitation Tissue
8005 Measurement of Relative Humidity

PRECISION—*Chairman,* C. A. BICKING

8000 Precision of Test Methods for Evaluation of Fluorescent Brightness

PULP TESTING COMMITTEE—*Chairman,* J. C. COUSINS

470 Determination of Pulp Consistency
636B Testing High Freeness Pulps

WAX TESTING COMMITTEE—*Chairman,* R. W. DANNENBRINK

487 Accelerated Test for Oxidation Stability of Paraffin Waxes
741 Revision of T 644 m-58, Tensile Strength Testing of Wax
742 Flow Tests

JOINT TASK FORCE—(PAPER TESTING AND PHYSICAL METHODS COMMITTEE) *Task Force Chairman,* R. B. HOBBS

8001 Heat Test for Relative Stability of Paper

Twelfth Testing Conference

Queen Elizabeth Hotel, Montreal, Que.
Aug. 15–18, 1961

ENGINEERING DIVISION

Committee Contribution

Electric Engineering Committee—Checking Performance of Motors with Sealed Insulation

THE relatively new sealed insulation systems being offered by motor manufacturers during the past few years might ultimately save the pulp and paper industry many dollars if they prove suitable under the very adverse operating conditions prevailing in our industry.

Because of the relatively newness of such motors it is probably too early to make a critical evaluation of their performance, especially based on the experience of any one person or company. But, by canvassing the industry, it should be possible to obtain some indication of how these motors are performing compared with those having conventional insulation systems.

Questionnaires are now being sent to the mills so that they can report their experience with motors having sealed insulation systems versus those with conventional systems. The results of this survey will be presented at the Washington Engineering Conference this October.

This project is under the jurisdiction of the Motors, Generators and Control Subcommittee whose chairman is R. J. Minges of the Gardner Div. of Diamond National in Middletown, Ohio. L. W. Porter, of St. Joe Paper Co., is in charge of the project.

Mr. Porter is counting on receiving an excellent response to the questionnaires because of the keen interest in this subject among the mills. This is rather important because, due to the relatively limited experience with sealed insulation systems, the sampling must be extra thorough.

Electrical Problems Involved in Utility Company-Paper Mill Plant Ties

Project No. 790

JACK DAVEY and H. H. MULLINS

This paper is the result of a joint study by the Louisiana Power and Light Co. and The Olin Mathieson Chemical Corp. plant at Monroe, La. The following problems are discussed: momentary outages (outages lasting less than 1 sec.) long time outages of the tie, momentary voltage dips, low frequency, failure of a remote circuit to trip on a fault, kilowatt tie line flow control, reactive tie line control, and increased fault current. The need of close cooperation between the utility and the paper mill is emphasized.

MOMENTARY OUTAGES

Outages Lasting Less than 1 Sec.

NORMALLY, when there is mill generation synchronized with the utility, instantaneous automatic reclosing is not used, and as such, momentary outages are not a problem. The usual solution in this case is to require that the tie be closed manually only after the plant generation and the system have been manually synchronized. Where generation is involved, automatic synchronizing can be employed. Even when generation is involved, instantaneous automatic reclosing following simultaneous tripping of both ends of the tie line is very successful when the outages have been caused by lightning. However, if the tie is a shielded line conforming to modern design criteria, lightning flashovers are minimized to the point that outages from this cause are no more significant than those caused by reckless drivers, for instance. This factor plus the complications of the plant generation practically rule out instantaneous reclosing.

This brings us to the usual problem caused by momentary outages which is the effect on a radial type load which has been assigned to the utility and does not involve any generation in the plant. This is a problem on which Louisiana Power & Light Co. has done considerable work since we have several continuous process chemical plants in our area.

Reliability of the source of modern utility power is shown from the experience of one paper mill, which during a 5-yr. period of purchased power, the outages (of any duration whatever) are less than one per year.

The two objectionable results of momentary outages are:

1. The dropping out of all a.c. solenoid devices. This includes motor starters, solenoid valves, control relays, etc.

2. The high currents that can flow for the first $^1/_2$ cycle after the service is re-established. If instantaneous overcurrent elements are used in feeder relaying, this can cause trouble.

When power is lost to a load consisting primarily of induction motors, the residual magnetism of the motors will generate a voltage which will decay to zero in about 60 cycles. Any shunt capacitors on the circuit can radically change the time constant of the decay rate and the maximum voltage magnitude.

Since power is re-established in less than a second, almost all the solenoid-type devices are picked back up again with no resulting difficulty. Unless motor starters are equipped with time delay undervoltage devices, they must be restarted manually. Only those motors vital to the operation of the plant should be equipped with the time undervoltage devices since it would be an unnecessary burden on the plant and utility system to start all motors simultaneously. All the other motors can be started manually later. Solenoid valves are often of the manual reset type because of safety and insurance considerations, and if so, they will have to be manually reset. Control relays can also be another source of trouble if they are used in a time sequence type of automatic control or automation. The short outage, in effect, makes the control scheme forget where it was and to try to start all over at the beginning of the sequence. It should also be stated that voltage dips caused by remote faults can cause the same troubles if the voltage dips below the drop-out point of the solenoid devices.

The voltage range on a.c. control devices is specified by NEMA to be 85 to 110% voltage. This range is determined by the minimum voltage that will pickup the devices and the

JACK DAVEY, Louisiana Power & Light Co., New Orleans, La., and H. H. MULLINS, Olin Mathieson Chemical Corp., Forest Products Div., West Monroe, La.

heat dissipation when normally energized. This has little or nothing to do with the dropout voltage of these devices, which is the factor with which we are primarily concerned on momentary voltage dips and outages. The normal characteristics of solenoid devices are that they will drop out somewhere between 30 and 75% of the pick-up voltage. Taking 75% of 85% results in a drop-out voltage of even the most sluggish devices of 64%.

A bad condition can develop when the plant is being re-energized with a low voltage following a momentary outage. If the voltage decreases just as the motor starter contacts touch, the contactor may not have sufficient pressure to continue its closing action; and as such then, the motor starting current surge may cause the contacts to weld. On many contactors the operating characteristics may be such that this phenomena cannot occur, but in any event, the probability of just the right voltage condition and variation occurring is slim. It is generally accepted that any voltage that will start a contactor moving will cause it to close fully, so that to have the contacts weld, the voltage must decrease appreciably just before or at the time the contact tips touch.

If solenoid valves and control relays are a problem, then the solution for a new plant would be to put in a control battery and trickle charger and use a d.c. control system. The control battery has some good operating advantages and should lower insurance rates since there is a source of control power when all other sources of energy are lost.

In an existing plant, the solution most often used is to install an induction motor driving a generator and flywheel. The generator serves all control devices. The inertia of this system prevents the short outages and voltage dips from appearing on the control system. The induction motor starter is equipped with a time delay undervoltage device which keeps the start button shorted out for a short period of time—i.e., 4 sec.—following an outage. If the source is re-established any time in this period, the motor restarts. There also has to be an automatic transfer scheme on the control power to change it to another source in the event something happens to the generator or routine maintenance is necessary.

The high currents that flow for $^1/_2$ cycle when the load is re-energized following a short outage are caused by the motor residual voltage being out of phase with the source voltage when the source is re-established. Assuming that the residual motor voltage is to be 100% and that it is 180° out of phase with the source and that there is a full offset, this half-cycle current can be about 20 times running current. The bottom oscillogram of Fig. 1 illustrates this effect. The whole figure also shows the effect of shunt capacitors on an induction motor's terminal voltage immediately after it has been tripped.

For many years there has been a controversy between the manufacturers and the utilities concerning the possibility of damaging the motors under these circumstances; however, speaking for Louisiana Power & Light Co., we have been following this practice for 30 yr. and have never damaged a motor yet. My theory on the apparent discrepancy between theory and practice is that the manufacturers treat the motor shafts as rigid members, whereas they are not.

This high pulse of current can trip instantaneous overcurrent relays if they are improperly set. Usually the necessity of coordinating with fuses and motor protective devices makes the use of instantaneous overcurrent relays impossible in any event.

All the previous comments about restarting motors following a momentary outage apply specifically to induction motors and not to synchronous motors. The problems of re-energizing a synchronous motor following a short outage are so complicated that the usual condition is to allow the machine to stop and be restarted after a time delay. Some of the problems to be considered if the motor is re-energized immediately are:

1. The motor field must be opened and enough time al-

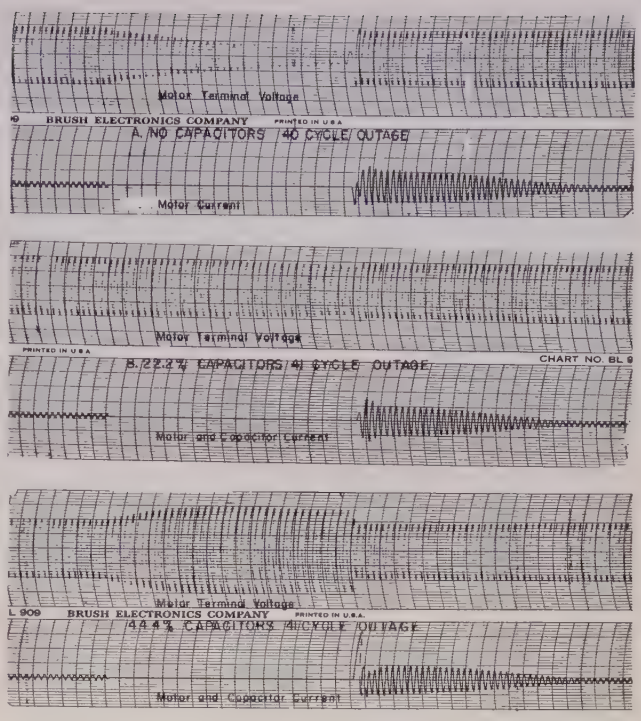
Motor Terminal Voltage
BRUSH ELECTRONICS COMPANY
A. NO CAPACITORS 40 CYCLE OUTAGE
Motor Current
Motor Terminal Voltage
B. 22.2% CAPACITORS 4 CYCLE OUTAGE
CHART NO. BL 9
Motor and Capacitor Current
Motor Terminal Voltage
L 909 BRUSH ELECTRONICS COMPANY
44.4% CAPACITORS 4 CYCLE OUTAGE
Motor and Capacitor Current

Fig. 1. Full load conditions on a 125-hp. induction motor driving a reciprocating compressor showing residual voltage and current surge following a 40 cycle outage. Curve A—no capacitors; curve B—22.2% capacitors; curve C—44.4% capacitors. Note the large initial $^1/_2$ cycle restarting current in the bottom oscillogram

lowed for the residual motor terminal voltage to become low enough so that a re-energization out of phase will not be too severe a shock.

2. If the motor is restarted under load and takes too long getting up to speed, the starting winding will be damaged.

The usual problem with a synchronous motor is to detect when the source has been lost and to disconnect the motor. Terminal voltage is an unreliable indication and the usual solution is to use an under-frequency relay or a directional power relay.

LONG TIME OUTAGES OF THE TIE

Any fault on the tie is accompanied by a voltage dip and possible frequency disturbance on the plant which can be minimized with fast relaying and circuit breakers until it is no problem. The principal difficulty with losing the utility tie occurs in the case where the mill does not have sufficient generating capacity spinning to serve its whole load. In this event, the mill will have to trip selected feeders until enough load has been lost to get back within range of the generation. This can, of course, be done manually, but the operators may not do it fast enough or may drop too much or too little load. Probably the best way to do this is with frequency relays set at various frequencies between 57 and $59^1/_2$ c.p.s. so that the least essential load is tripped first at 59.5 c.p.s. and the most important at 57 c.p.s. The 57 c.p.s. level is chosen because, from our utility experience, this is the point at which the boiler auxiliary equipment will start having trouble keeping enough water in the boiler, maintaining sufficient draft, etc. Steam auxiliaries will, of course, change this picture.

The modern paper mill, using d.c. drives with amplidyne or rototrol control systems, is not sensitive to frequency variations. This is demonstrated by the following example: if the a.c. system frequency decreases, the speed of the motor-generator set decreases in almost direct proportion. This decrease in generator speed tends to lower the motor-generator set d.c. output voltage. This decrease in d.c. voltage is recognized by the voltage regulator which acts to increase the shunt field current and bring the d.c. voltage back to

normal. So, as far as all the d.c. drive motors are concerned, no change has taken place and the paper machine is still operating at the same speed, requiring the same power to drive it. Olin Mathieson, in West Monroe, La., with a total of five papermaking machines, all of which are d.c., has made a test showing the following result: with a generated load of 20,800 kw. at 60.2 c.p.s., the frequency of the system was lowered by means of the turbine governors to 59.0 c.p.s. The load fell off to 20,200 kw. or only 2.88%. No abnormalities in papermaking or other plant disturbances occurred. Interpolating these figures, a 1 cycle change in frequency would cause a 2.4% change in load.

A typical utility will experience about a 10% drop in load for each 1 cycle drop in frequency. If the mill generation has electric boiler feedwater pumps, its lower response will probably cause the mill generation to have difficulty carrying its load at some frequency higher than the 57 c.p.s., which is the lower frequency limit on utility systems. Therefore, the mill load shedding equipment should operate to shed the most essential load at about 58 c.p.s. to save its power plant. This conclusion has been derived only from the data on this particular plant and should not be applied generally.

Some consideration should be given to preventing the load shedding equipment from operating if the low frequency condition occurs while the utility tie is closed. The utility itself may be experiencing a system disturbance, and probably the best thing for the paper mill to do is to open the tie and take care of their own system. The utility involved can give its past history of such disturbances and their estimate of future conditions.

In any event, whether or not the paper mill has sufficient spinning reserve to take care of its own load, the turbine governors and steam extraction mechanisms must operate rapidly and have little tendency to hunt when the load is suddenly applied. The generator voltage regulators should also operate rapidly and with stability. Modern voltage regulators use a field forcing technique which operates as follows: if, for instance, a 10% change is necessary, the regulator will produce a voltage which would result in a 100% change if it remained. Just before the 10% change is reached, this 100% field forcing voltage is reduced to zero. This is a very rapid type control.

MOMENTARY VOLTAGE DIPS

Since the utility system is much more extensive than the plant electric system, the utility system will experience many more faults than the plant. Nearby faults on the utility system will cause a voltage dip on the plant, and the further away the fault is, the less severe the dip. By using good line design techniques and modern relaying the utility can limit the number and duration of the faults, but it cannot eliminate them. The probable situation is that these dips will still be frequent enough that the mill will have to protect itself from the bad effects.

A momentary voltage dip causes the same effect that the momentary outages cause on a radial load in that the a.c. solenoid devices drop out momentarily. The solutions are also the same as those described under *Momentary Outages*—time delay undervoltage devices on the motor starters, and the development of a reliable source of control power.

In many cases the plant generation will be large enough and the impedance of the tie and series transformer high enough that faults in the utility system will not drop the voltage on the plant system below the drop-out of the solenoid devices which is roughly about 50% voltage. No protection will be needed in this case.

LOW FREQUENCY

When trouble occurs on a utility system of catastrophic proportions, it usually causes the system to split into several small pieces. Some of the parts will have more generation than load, and will have a high frequency until the generator governors and other automatic control equipment can correct it. Other portions will have more load than generation, resulting in a low frequency and in the necessity of having to shed load to bring the frequency up to 60 c.p.s., making it possible to synchronize with other parts.

If a paper mill having generation synchronized with the utility happens to be in a portion experiencing low frequency, the automatic turbine governor action in attempting to maintain 60 c.p.s. will cause power to be exported by the paper mill to the utility. If this action plus that taken by local utility power plants is not sufficient, the frequency will continue down and it will be up to the paper mill to trip its tie at about 57 or 58 c.p.s. to save itself from going down with the utility. Manual action will probably be fast enough in this case, if the power plant operators have been given the proper instructions previously. Frequency relays set to trip at 59.5 c.p.s. are probably the best solution, however.

Difficulties of this nature occur very rarely, on the order of once every ten years, and a study of the utilities' past performance and the location of the mill in the utility system will give a good indication of what can happen.

THE FAILURE OF A REMOTE CIRCUIT TO TRIP ON A FAULT

Should a circuit breaker out in the utility system fail to clear a fault in the vicinity of the paper mill interconnection, then the standard relaying on the mill interconnection can probably "see" the fault and clear after a time delay. The most serious situation, as far as the mill is concerned, is to have the paper mill breaker on the interconnection fail to trip for a fault on the interconnection. The first thing to realize in a situation like this is that the mill is probably going to be shut down and the problem is how to do it in the fastest, safest, least expensive way. A method commonly used in utility systems to solve this problem is to use a backup bus clearing scheme which will trip all other breakers energizing the bus to which the defective breaker is connected. This is the fastest scheme and will trip a minimum of plant load, but probably enough to shut down the whole plant anyway.

The mill probably has nondirectional overcurrent relaying in the breakers energizing the bus, and if this is the case, these breakers can trip the bus and accomplish the same result as a bus clearing scheme. The fault current decrement curve of the plant generators will have to be considered in investigating this case.

If some sort of bus clearing scheme is not available, then another way the problem can be solved is to install negative sequence relying on the generators to protect them from unbalanced faults and to rely on the operator to trip manually on balanced faults which do not constitute any danger to the generators. This still leaves the possibility of an arcing fault and maybe a fire in the defective breaker subject to long time clearing by the negative sequence relaying or the operator.

It should be stated that the breaker on the utility tie is not the only one that can fail to trip on a fault. The same circumstances will probably prevail if almost any breaker in the plant fails to trip.

KILOWATT TIE LINE FLOW CONTROL

When tied with a utility, the plant frequency will remain 60 c.p.s. regardless of the plant load. Because of this, the mill speed governor controls will not function and the result will be that all load swings will be passed on to the utility if something is not done. The demand clause in the utility rate will make it economical for the mill to install equipment to make the mill generation take the loads wings and to allow only the scheduled interchange to flow over the tie. The utility can exercise no control over the amount of power taken by the mill.

The tie line control equipment is relatively simple and usually operates to control the condensing unit's governor setting. It does this by pulsing the generator's governor motor until the generator has brought the tie line flow back to schedule. The control scheme must not be faster than the generator response otherwise a hunting condition will develop. It is an unusual circumstance to control the generation of the extraction or back pressure machine since its electrical output is usually determined by the process steam requirements.

The control system is simple as long as the corrections necessary remain within range of the condensing unit. When this is not the case, some of the power generated by the back pressure machine will have to be shifted to the condensing machine to bring it back in range. Assuming the process steam requirements remain constant, the amount of steam flowing through the back pressure unit will have to be reduced and the flow through pressure reducing valves by-passing the back pressure unit increased.

Since the electric energy requirements, the process steam requirements, the amount of by-product fuel to be burned, and the woodmill load are relatively unrelated variables, a discussion of the general case is beyond the scope of the paper.

REACTIVE TIE LINE FLOW CONTROL

The contract between the mill and utility probably contains a power factor penalty clause to encourage the mill to hold its power factor above a certain level. In the usual case, the automatic voltage regulator on the mill machines plus occasional manual adjustment will accomplish this.

If the mill is tied directly into the utility transmission system, depending on where it is located, it will be affected by the periodic voltage change the utility makes to maintain the voltage relatively constant on its load. This change is from about 100 to 103% in the summer, and 99 to 101% in the winter. The closer the mill is to a utility generating plant, the more of this swing it will see. If the mill voltage regulators are set to maintain zero reactive interchange at the peak utility voltage, then the mill will be sending reactive to the utility on the minimum utility transmission voltages. If this is objectionable, then the mill can make manual corrections to avoid it.

This discussion assumes that the proper voltage tap has been chosen on the tie transformer to allow adequate mill voltage throughout the range of the utility voltage variations. An unusual case might call for a seasonal change of the no-load taps in the tie transformer, or an extreme case might call for tap changing under load equipment in the tie transformer.

In any event, however, the mill should operate its generators with as much field current as practical to minimize the voltage disturbance and to improve stability when the utility tie is faulted and/or lost. This could result in the mill always sending some reactive to the utility.

INCREASED FAULT CURRENT

Any time a plant grows and additional power supplies are added, the fault current and, therefore, the interrupting duties on the circuit breakers increase. This is true whether the additional power source is a utility tie or a new generator. The significant difference between the two is that the rate of decay of the fault current is much slower from a utility tie than from a plant generator. This may not be important since the tendency will probably be to trip any breaker as rapidly as possible on a fault anyway.

If there is a problem with interrupting capacity of existing breakers, the following list outlines several possible solutions:

1. Replace the breakers with new, larger interrupting capacity units.
2. Delay tripping until the mill generation fault contribution decays to a point where the total current through the breaker is within its interrupting capacity.
3. Install fault detecting relays that will trip the utility tie, then the breaker in question, and then allow the utility tie to reclose at high speed.
4. Install reactors at the appropriate place to limit the current within the rating of the breakers.

The fact that there is an interrupting capacity problem probably means that someone in the past did not adequately foresee the growth possibilities and should serve as a reminder to the present engineers not to make the same mistake in the installation being contemplated.

SUMMARY

There is always some reluctance to discuss a subject generally for fear that some particular aspect may be entirely neglected or that some other point might be emphasized out of all proportion when an attempt is made to study a particular problem in light of the points discussed in the paper.

A point that should be emphasized is the need for a close cooperation between the utility and the paper mill and the inadvisability of a utility to either overstate or understate the anticipated quality of its service.

Not enough can be said about the paper mill giving serious consideration to future growth possibilities and in making present designs fit into the ultimate scheme. If possible, the utility should be informed of these future plans.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960

Protecting A.C. Motors Project No. 857

H. A. WRIGHT and T. F. BELLINGER

The purpose of Project 857, was to collect into one article a complete brief of all phases of a.c. motor protection. This has been found to be necessary due to the fact that existing material on the subject has not been gathered together in simple usable form. This treatise will also be used as a basis for further detailed studies and expansion in certain areas. This paper treats in detail the following protective features available in a controller: (1) overload protection; (2) locked-rotor protection; (3) short-circuit protection; (4) undervoltage protection; (5) open phase, phase unbalance, and phase reversal protection; (6) ground fault protection; (7) incomplete sequence protection; (8) pull-out protection; (9) loss-of-field protection; (10) starting winding protection; (11) embedded motor temperature protection; (12) insulation protection.

Adequate and complete protection for large a.c. motors and their circuits presents a problem to the electrical engineer. He must make the decision on how much protection is necessary. He should also bear in mind that overprotection is almost as bad as underprotection. The maintenance of the control becomes quite involved, with the result that considerable downtime is charged to the equipment. The application to a large extent determines the type and amount of protection required.

Also, we should remember that the motor may be considered to be an eager beaver, not knowing when to give up. While, in general, a motor can handle very large short-time overloads, its capacity to do work without injury to itself is determined by the amount of internal heat generated and dissipated. This discussion, therefore, will cover the protective features available in the following order:

1. Overload protection
2. Locked-rotor protection
3. Short-circuit protection
4. Undervoltage protection
5. Open phase, phase unbalance, and phase reversal protection

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6. Ground fault protection
7. Incomplete sequence protection
8. Pull-out protection
9. Loss-of-field protection
10. Starting winding protection
11. Embedded motor temperature protection
12. Insulation protection

1. OVERLOAD PROTECTION

Overload protection should permit the motor to operate at its full capacity yet protect it from unusual conditions of mechanical load. While high-motor temperature causes deterioration of the insulation, Fig. 1, there is no one definite value immediately above which the motor windings would be damaged or below which they would last indefinitely. Since the core and bearing losses of motors are a low percentage of the total losses, it therefore follows that a measure of electrical current which produces the copper losses is a proportionate measure of the motor temperature. This principle is the basis for design of current operated overload relays.

Overload relays are of two general types: thermal and magnetic. The thermal overload relay is so designed that its thermal capacity resembles the heat characteristic of the motor (Fig. 2).

Thermal overload relays are of two general classes: melting alloy and bimetallic. The melting alloy type is not adjustable and cannot be obtained with an automatic reset feature. As a general rule, it is a simpler and sturdier device than the bimetal and will maintain its accuracy over a longer period of time. While both types are widely used, the bimetal types are more adaptable to automatic reset and adjustable characteristic features.

Magnetic overload relays are also of two general types: instantaneous and time limit.

Magnetic overload relays are generally of the time limit variety. However, since this type is less responsive to an integration of the motor current, it is to be generally applied to

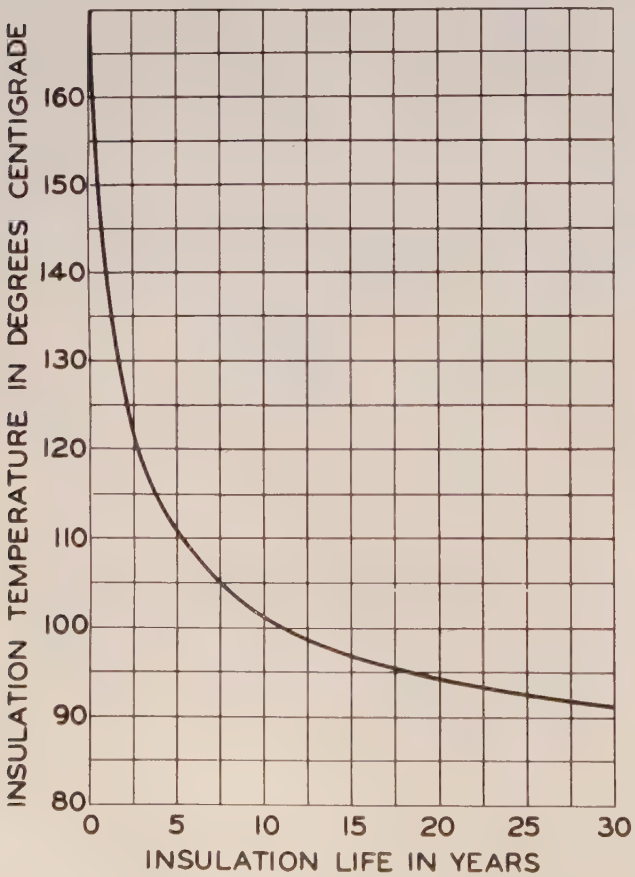


Fig. 1. Relation between insulation temperature and motor life in years

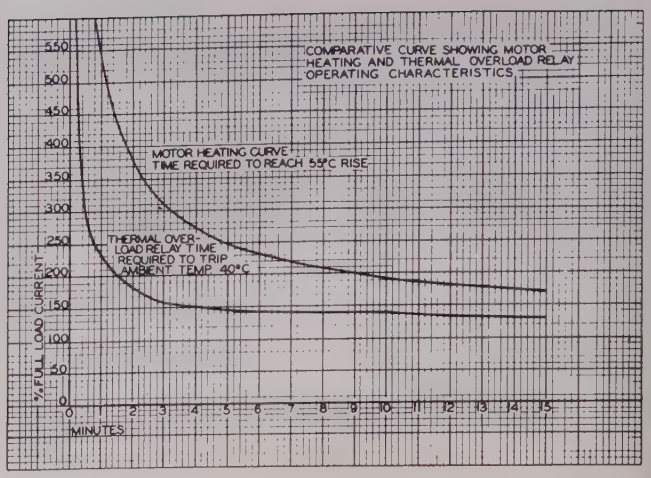


Fig. 2. Comparative curve showing motor heating and thermal overload relay operating characteristics

a specific condition of overload (a definite percentage of current and the time of its existence). The time-limit feature of overload relays is obtained either by using a dashpot or by using an escapement mechanism.

Instantaneous relays are of similar construction but are without the time-delay feature. The chief disadvantage of magnetic relays is that they do not compensate for repeated starts or temperature buildup in motors caused by fluctuating loads. They are, however, more accurate for definite current and time-overload conditions. Magnetic overload relays are also obtainable having a combination of time-limit and instantaneous trip feature. However, care is needed in applying this type to industrial control. Consideration must be given to the fact that the switching device may not have sufficient capacity to interrupt a short-circuit condition.

The selection of overload relays to protect against excessive mechanical load is not as simple as it has been treated. The load may be one of three types: *constant*, *fluctuating*, or *long time starting*. The constant load condition is normal for most electrical drives and in this case it is very simple to select overload relay heaters to give the proper protection. The practice in connection with *fluctuating loads* appears to be to increase the size of the heater until the control does not trip under the fluctuating load. Of course, this is obviously the wrong approach. The safest approach is to determine by actual tests that the motor does not overheat during the maximum load cycle and then select a rating of heater elements for the overload relays that will trip when over-temperature is reached. The ratings of heaters selected will usually be larger than those required for steady-state load conditions. Stalled rotor and single-phase protection of course will be sacrificed to a certain extent.

When actual testing for selecting the proper size of heater elements is impossible, a different approach will be necessary. The effective loading of the fluctuating load can be obtained from the root-mean-square value of the motor current. If the load characteristic data used for selecting the motor are available, the effective current can be obtained by the use of a planimeter. Since this information is not often available to the motor user, a more practical way to obtain the effective loading of the driving motor is to determine the root-mean-square value of the current from a chart of a recording ammeter. A current transformer ratio should be selected so that the maximum current will fall within the limits of the chart. The speed of the chart should be set fast enough to read the build-up and decay of the peaks. Usually 3 in. of chart a minute is satisfactory. The chart should cover an operational cycle for the maximum expected loading.

Another problem to which there really is no answer is that the overload relay cools more rapidly on the off-peak cycle than does the motor, due to the great difference in mass. One possible solution would be to use two sets of overload re-

lays for drives experiencing wide fluctuations. One set of overloads with automatic reset feature could be selected for approximately 100% load and would be used to operate an

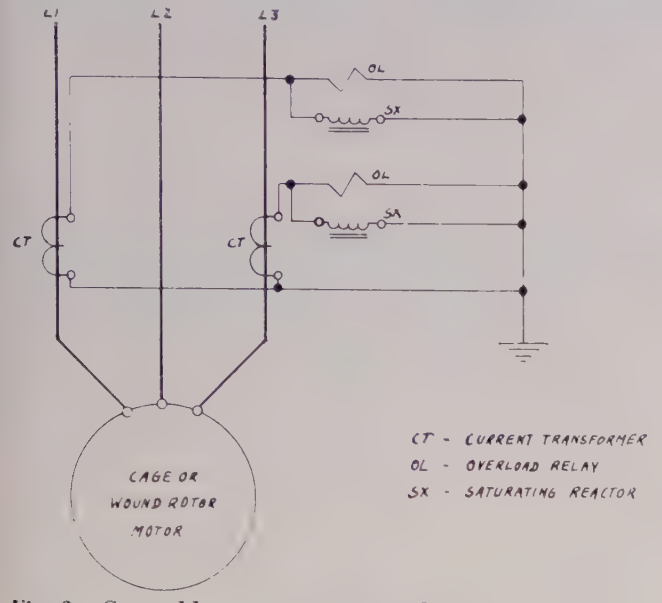


Fig. 3. Saturable reactors connected in parallel with the heater elements of the overload relays

alarm or other warning device. The second set of overload relays would be selected to operate above the full-load point and would operate to shutdown the equipment. This arrangement is really only effective when the operator has control of the fluctuating load.

The next type of load which would give difficulty in selection of overload relays is a blower which has a *very long accelerating period.* Thermal overload relays have a tendency to over-protect the motor during acceleration by operating several seconds after the motor has reached rated speed, although the current at this time may be at full-load value or less. The temperature increase of the relay heater coils may cause them to become a dull red color while the starting current persists. However, the operating temperature will lag several seconds behind the temperature of the heater coils. As a result of this heat lag between the heater coils and bimetal, the relay may trip several seconds after the motor current has been reduced to the normal value. For this reason, only about 50 to 75% of the tripping time characteristic at high currents can be utilized, as the relay may trip before the motor has reached maximum allowable temperature. Trying to correct this by using the next higher size heater will sacrifice running protection. One method is to by-pass the heaters during the starting cycle. While this sacrifices starting protection, it does provide proper running protection. Sometimes this is the only economical solution. A second method is to use two sets of overload relays. One size provides running protection and is shorted during starting, and the other size provides starting protection. This method is quite satisfactory, but the control circuit is more complex.

A simple and reliable method which prevents the overload relays from unnecessary operation during the accelerating period and yet provides adequate motor protection from overheating is with the use of saturable reactors. As shown in Fig. 3, the reactors are connected in parallel with the heater elements of the overload relays.

The reactors are constructed with a small air gap and applied in such a manner that the reactor iron becomes saturated at values somewhat above 200% full-load current, tending to keep the value of the current through the heater elements relatively constant as the motor current increases above this point (see Fig. 4). As the current falls below this point, the iron is unsaturated and the reactor impedance becomes very large compared to that of the heater elements. In this way the overload relay operating characteristics are extended on starting currents. The reactors shunt about 2% of the current from the heaters during normal operation, which produces a negligible error into the relay operating characteristics. The characteristics of the relay with and without reactor are shown in Fig. 5.

Overload relays normally protect against locked-rotor conditions; however, the length of time the motor will safely endure locked-rotor current, both under polyphase and single-phase conditions, should be checked. This value should be checked against the relay tripping time from the characteristic curve. For further information on this subject, see section 2—Locked-Rotor Protection.

Single-phase operation due to open circuit in the transformer primary has been a subject which has been discussed in several previous papers. If the transformer primary connection is wye-wye or delta-delta, two overload relays will provide adequate protection; however, if the transformers are connected wye-delta or delta-wye, it is necessary to use three overload relays.

There are other factors which influence the need for three-phase overload protection:

1. Three phase and single phase loads on same branch circuit.
2. Large and small motors on same branch circuit.
3. Initial cost of the motor.
4. Down time to change out motor if it fails.
5. Corrosion of relays.
6. Possible future changes in the system.

Since there are so many variables and unknowns affecting the decision to use two or three overloads, it is recommended that three be used as a standard.

Another condition which should be mentioned is the influence of ambient temperature on the tripping characteristics of thermal overload relays. For larger motors there are available a number of temperature compensated overload relays. The use of these relays will eliminate the necessity for the considerations which follow. Standard overload relay heater units are assigned ampere ratings based on an ambient temperature of 40°C. in open air; for a given heater unit the ampere rating assigned is the current at which it will trip at 40°C. in open air.

Under ordinary conditions where the motor and controller are operating at the same ambient temperature, proper pro-

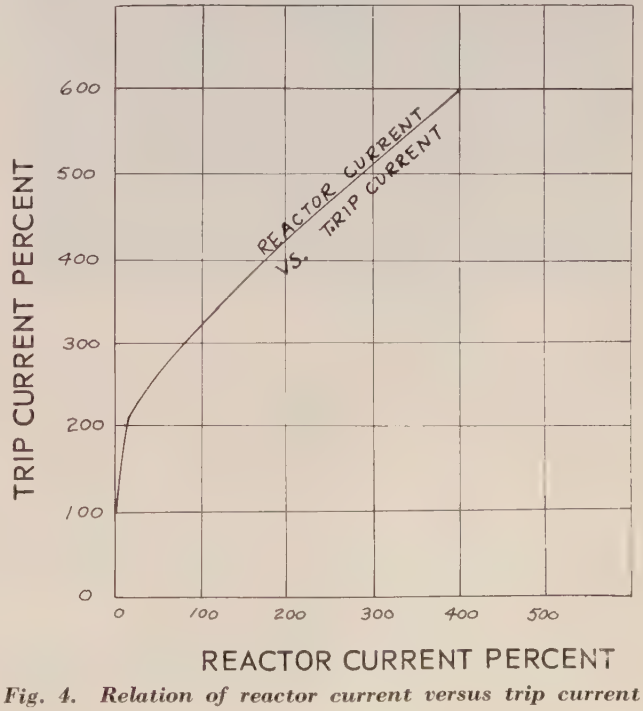


Fig. 4. Relation of reactor current versus trip current

tection of the motor will be maintained following the multiplier listed in the table below:

Temperature, °F.	*Multiplier for full-load current*
68–86	1.
95	1.05
104	1.1
113	1.16
122	1.24
131	1.32
140	1.4

When the motor operates at an ambient temperature different from that of the controller, a change in the size of the heating unit may be indicated. This value may be different for different manufacturers, but for a specific manufacturer and a particular size relay, a change in one heater size will compensate for a 15°C. difference in temperature between the motor and controller. If the motor is at a higher ambient, a lower rating of heater is used, while a higher rating is used if the controller is operating at a higher ambient.

Semienclosed and total-enclosed, fan-cooled motors have temperature rise ratings greater than the 40°C. rise for open type motors. The 40°C. rise motors have a continuous service factor of 1.15, which means that these motors can be operated continuously at 115% of name plate rating. Motors having greater temperature rise ratings usually have a unity service factor, which means that the motors are without overload capacity. Most overload relay selection tables are setup for the 40°C. motors and provide for 115% load operation. When selecting relay heater elements for motors having unity service factors, the general rule is to select the next smaller heater element than is indicated for the 40°C. motors. The trip rating of the heater element when applied with unity service factor motors should be approximately 87% of the trip value indicated for the 1.15 service factor motors listed in standard selection tables. If the motor has a nameplate rating of other than 40°C. be sure to check the service factor. For example, 50 or 55°C. have a unity service factor.

2. LOCKED-ROTOR PROTECTION

Thermal overload relays and induction relays provide for motor running conditions. Another condition presents itself when the motor fails to start, which may be caused by mechanical fault conditions of the load or of a single-phase line. The question then is, will the motor running protection provide for locked-rotor protection? To determine this it is first necessary to know the length of time the motor will safely endure locked-rotor current under polyphase and single-phase conditions, and second, the locked rotor current under both conditions. The latter information is used to determine the relay tripping time by use of a curve showing the relationship between relay current and tripping time. A comparison of this time with that of the motor endurance under locked-rotor conditions will indicate suitability of the relay.

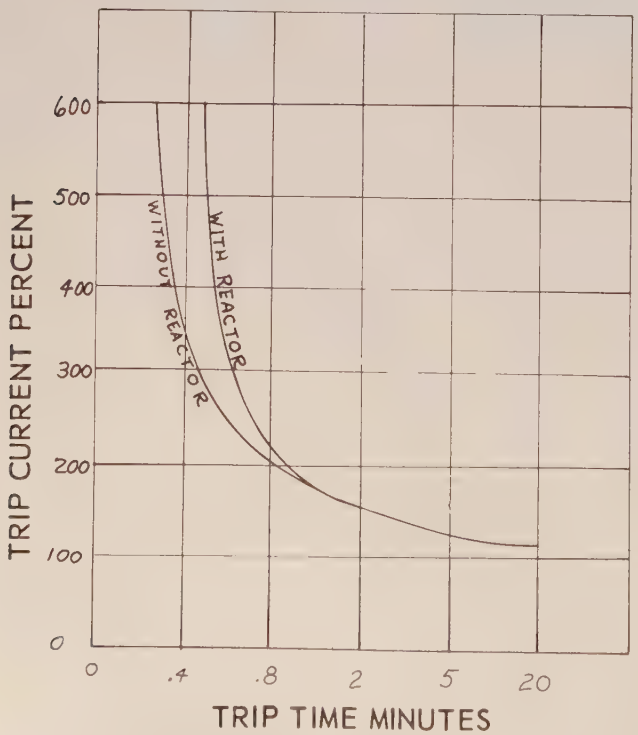


Fig. 5. The characteristics of relay with and without reactor

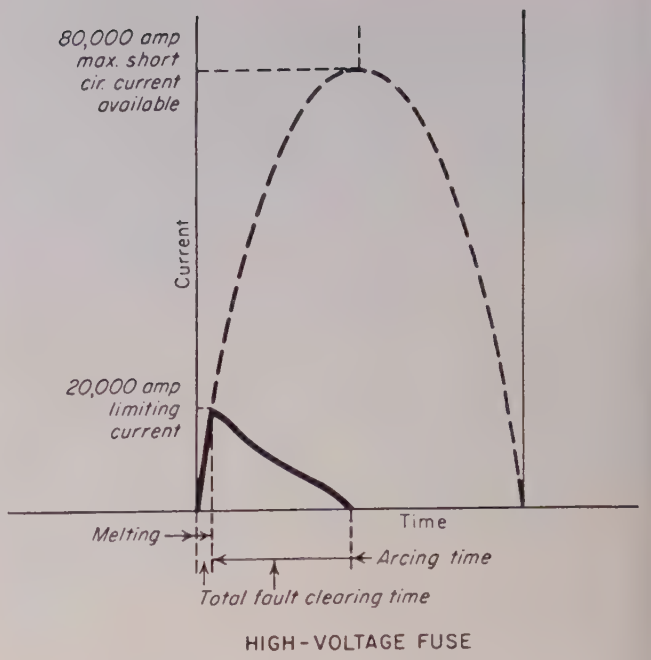


Fig. 6. Operating characteristics of high interrupting capacity current-limiting fuses on short-circuit interruption

Solid curves are the actual fault currents permitted by the fuse on interruption tests. Dotted curves indicate the fault that would flow if interruption had not occnrred.

Under single-phase locked-rotor conditions the actual line current will be approximately 86.5% of the inrush current under polyphase locked-rotor conditions. This lower current will, of course, increase the relay tripping time and again a comparison with motor endurance time corresponding to single-phase locked-rotor conditions should be made. This does not quite hold true for a delta-connected motor. In this case the phase current will also be 86.5%, however, the current in the windings will be full current in one winding and half normal current in each of the other two windings.

If the driven machine is subject to frequent jams, an instantaneous induction relay can be used to give added protection. However, adding a "jam relay" for locked-rotor protection creates some additional control complications, due to the fact that the relay must be inoperative for the motor acceleration period. One method is to add a timing relay to setup the tripping circuit after the motor has reached normal speed. This application is most common on wound-rotor motors used for driving crushers and similar loads where stalling during operation is probable. In this case, jam or stall protection is introduced on the completion of the last accelerating step. Another method is to use a zero-speed switch on the motor in place of the jam relay. It is then necessary to by-pass the tripping circuit with a contact on the pushbutton, or by similar means, until the zero-speed switch closes its contacts on acceleration.

The jam relay may be adjusted for values below that of locked-rotor current to limit the maximum running torque or current of the motor to a definite value. This may be necessary in certain continuous processes where an increase in running torque over normal would indicate a failure in the process and it would be desirable to shutdown the whole process.

3. SHORT-CIRCUIT PROTECTION

Short-circuit protection is provided through the use of the inherent capability of the switching device, circuit breakers,

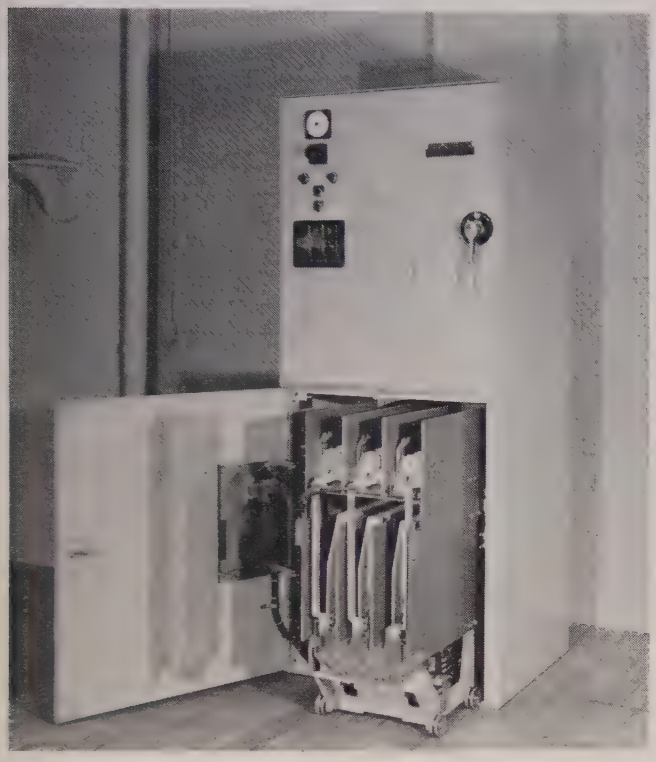


Fig. 7. High capacity fused controller

and fuses. Low voltage and high voltage differ in the type of protection offered, therefore, are handled separately.

Low Voltage (600 v. and Below)

This field has been covered before and offers no real problems, since adequate equipment is available. The user has a wide choice because little hazard exists. Short-circuit protection is generally provided through the use of combination motor starters. The smaller motor starters, connected to feeders of limited short-circuit capacity can take advantage of this limited capacity by employing fused starters having standard, NEC fuses rated 10,000 amp., or plastic case circuit breakers rated 7,500 to 35,000 amp. If available fault current exceeds the above capacities of standard combination starters, one may employ 100,000 amp. current limiting fuses or special plastic case circuit breakers having integrated coordinated current limiting fuses within their cases.

Large motors, connected to feeders of corresponding larger fault currents have current limiting fuses, suitable for 200,000 amp. fault currents; fuses for starters of this style are of the disconnect type. Circuit breaker combination starters, employing drawout or stationary large air circuit breakers are available having fault interrupting ratings of 25,000 to 100,000 amp. (varies with voltage).

High Voltage (2300 to 5000 v.)

The main line contactor can furnish short-circuit protection up to and including 50,000 kva. at 5 kv. If the capacity of the line is greater than 50,000 kva. current limiting fuses must be used. High voltage industrial control equipment cannot be protected by a backup breaker. Here it is necessary to go back to the difference between the breaker and the contactor. The contactor is magnetically held, requires voltage in order to keep it closed, while the breaker is held by means of a latch. A short circuit on the phase supplying the contactor holding coil will result in the loss of sealing power and the contactor will drop open. Its dropout time is relatively few cycles.

High speed (8-cycle) backup breakers are normally set to open in a time somewhat longer than 8 cycles. When using backup breakers, there is a zone from the time the contactor drops (3 to 4 cycles) to the time that the backup breakers open (8 to 20 cycles) that the contactor arcs severely, since it cannot interrupt the current over its rating. Oil-immersed contactors will explode and air contactors will be severely damaged. Therefore, high-capacity, high-speed fuses were developed to provide the protection that cannot be provided by circuit breakers. These fuses are designed to blow in less than $^1/_2$ cycle, as shown in Fig. 6, which is considerably less than the dropout time of the contactor. This fast fuse operation has resulted in wide application and acceptance of fused controllers like that shown in Fig. 7.

A fuse is made up of an insulated barrel filled with pure quartz sand. Running through this sand, from top to bottom, are a number of parallel conductors of silver wire or ribbons. Current-limiting characteristics are obtained on fuse blowing by the progressively increasing arc resistance.

The arc energy of fuses is absorbed by the melting of the quartz sand. Inspection of a fuse after it has blown will show glass tubes where the arc heat has melted the quartz. Fuses are obtainable in a number of different sizes. The fuse is selected from motor data covering full-load current and locked-rotor current. The energy dissipated by the fuse is based on I^2R. Therefore, a fuse curve plotted as time in seconds and current in amperes will follow a squared curve—

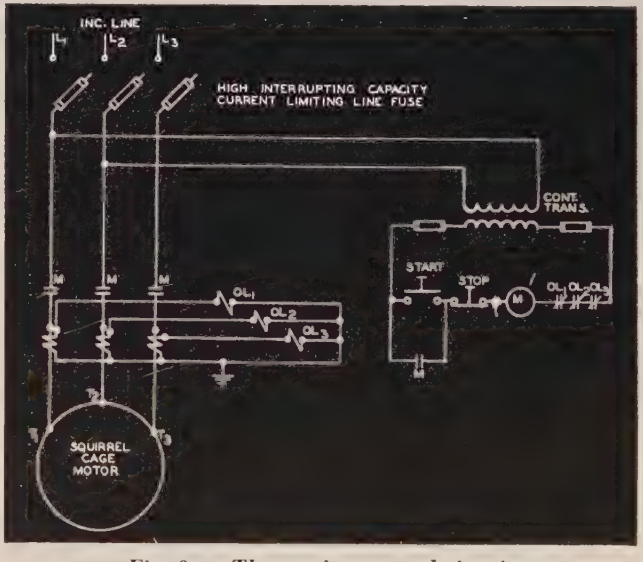


Fig. 8a. Three-wire control circuit

inverse time characteristic. If the fuse is properly selected, it will not blow on starting current.

4. UNDERVOLTAGE PROTECTION

Low Voltage Protection

Low line voltage, often referred to as undervoltage, is without doubt the most common hazard of motor performance It prevents motors from reaching rated speed on starting, and causes motors to lose speed and draw heavy overload currents while running. Protection from the overcurrent conditions is provided by the overload relays, but they operate after a time delay depending upon the degree of the overload and the

characteristics of the relays. When severe low voltage conditions develop, the motor should be cleared from the line as quickly as possible. This gives the motor a greater degree of protection and prevents "bogging down" of the entire power system.

Protection from low line voltage or complete loss of line voltage is a standard feature on a.c. motor controllers. This protection is provided inherently, because the line switches or contactors are maintained closed by a potential taken directly from the motor line or from a control transformer. The line contactors will close on 85% or less of line voltage and open if the voltage is decreased to a point somewhat less than the pickup voltage. This point is usually 50 to 70% voltage. If a severe voltage dip or a complete loss in line voltage should occur while the motor is running, the line contactor will drop open. When "three-wire" control circuits are used, as the one shown in Fig. 8a, the contactor circuit is maintained through an auxiliary control contact in parallel with the start pushbutton. If the contactor should open due to low line voltage, the coil circuit is broken by the auxiliary control contact and the motor cannot restart until the start button is operated. This type of protection is referred to as *three-wire control and low voltage protection.*

If the control contact is omitted and the start-stop pushbutton replaced with a knife switch, pressure switch, or other type of maintained contact device, the "two-wire control" circuit of Fig. 8b would result. With this scheme, the line contactor will open on low or no line voltage to shutdown the motor, but the motor will restart when sufficient voltage is restored to close the line contactor. This arrangement is referred to as *two-wire control and low voltage release.* The two-wire control arrangement has the disadvantage that several motors on the same power system would attempt to restart simultaneously after a voltage outage. Normally, such a strain placed on a system may drag the voltage down to the point where the motor would never be able to accelerate to full speed.

When two-wire control is required, overload relays with automatic reset features should not be used. Under such a condition, an overload would cause the overload relays to shutdown the motor, but the motor would be restarted when the relays had reset. This cycle could continue until the motor was damaged. Standard controllers will provide either

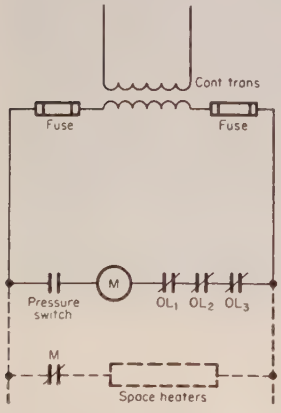


Fig. 8b. Two-wire control and space heater for motor

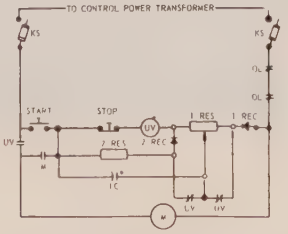


Fig. 8c. Three-wire control with time-delay undervoltage protection

low voltage protection or low voltage release, depending upon which of the initiating circuits in Fig. 8 are used.

A third arrangement, which combines features of two-wire and three-wire control, is referred to as *time-delay undervoltage protection.* This arrangement is shown in Fig. 8c and consists of a time-delay relay, U.V., which maintains a sealing contact for a definite period so that the motor will restart if the line voltage has been restored before the expiration of the time delay. If the voltage is not restored by that time, the motor cannot start until the start pushbutton is operated. The purpose of this type of protection is to permit continued motor operation after voltage dips or failures of short duration. Again, the disadvantage is that several motors could attempt to restart simulatneously if the line voltage was re-

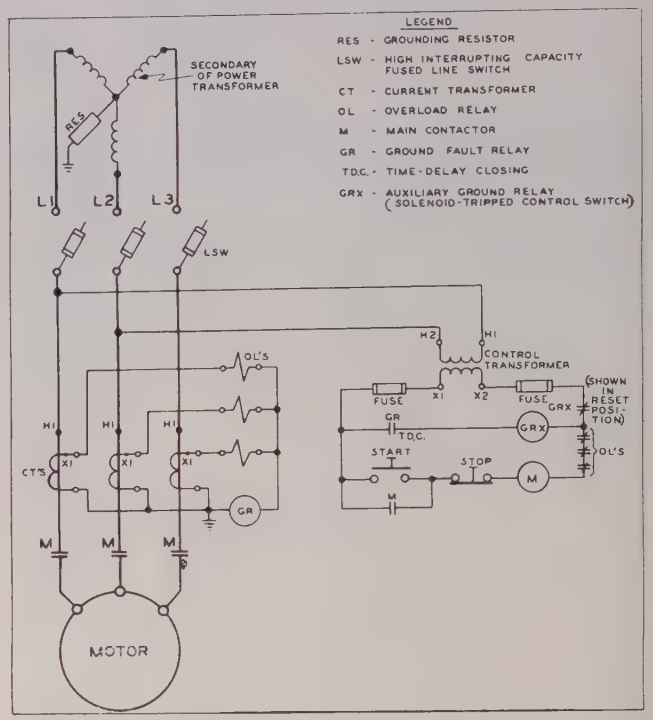


Fig. 9. Ground fault protection using overcurrent relay

stored before the time delay had elapsed. Time-delay undervoltage protection can be furnished on certain types of high and low voltage controllers, but it is not generally recommended unless the maintenance of service is essential and sufficient system data is available.

In lieu of the dropout feature of line contactors, a more accurate type of low voltage protection is available that will open at a definite calibrated point of voltage dip or complete failures. This protection is provided by adjustable relays that can be accurately set for a definite value of dropout voltage, usually 70% of rated voltage. Overvoltage protection is also available with a similar type of relay that is accurately adjustable for a definite value above rated motor voltage. Some special relays provide for both undervoltage and overvoltage with the same device.

5. OPEN PHASE, PHASE UNBALANCE, AND REVERSE PHASE PROTECTION

Although overload relays provide for adequate protection against open-phase operation in most cases, there are relays that are specifically designed to give protection against open-phase and phase-unbalance operation. These relays give protection under some conditions where overload relays would not operate.

Relays designed for this purpose have their elements placed directly in series with the motor phases or in the secondaries of phase current transformers, as are overload relays. Phase currents cause forces to be setup in a disk which remains in a set position on balanced phase conditions but rotates to operate its contact when unbalanced or open-phase conditions exist. The relays are adjustable for various ranges of load currents. Their operation may be time delay or instantaneous, and they will operate on 25% phase unbalance or any condition that will produce 100% load current or more in the phase having the largest current. Overload relays would require several minutes to operate if an open-phase condition

should develop on a lightly loaded motor. Single-phase operation of polyphase motors not only causes high current in the remaining winding, but also results in severe vibrations that could damage the motor and the connected equipment. It also causes line disturbances that could result in an unstable system.

Overload relays will not provide complete protection for a synchronous motor that operates unloaded if an open phase should develop. A condition could exist where the current in the remaining phase would not be of a magnitude to operate the overload relays but a high double-frequency current would be induced into the starting windings. These windings have a short-time rating and will be damaged if the motor is not shutdown. If the motor is overloaded, the overload relays will operate after a time delay, depending on the magnitude of the current and the characteristics of the relays. However even under this condition the relay operating time may be too long to prevent damage to the starting windings. The only way to be certain that the overload relays will adequately protect the motor under this condition is to check with the motor and controller manufacturers. If there is any doubt regarding the degree of protection, an open-phase or phase unbalance relay should be considered. These relays can be adapted for almost all types of motor controllers.

Phase Reversal Protection

Protection against the reversal of rotation of a polyphase motor is provided by a special type of relay that shutsdown the motor on reversal of the connection of any two of the phases but remains inoperative when the desired phase sequence is maintained. The relay may be of the type that operates on phase current or phase potentials. Each type consists of a rotating contact-actuating disk acted upon by a system of electromagnets. Because of its versatility, the potential type of phase reversal relay is more widely used.

Protection against reversal of rotation should be considered for any application where reversal could result in the loss of life, equipment, and processes. Such protection is usually required for the operation of elevators, conveyors, hoists, ventilating fans, and pumps. The possibility of phase reversals usually exists where alternate or emergency power systems are used or where the transmission line is subject to frequent alterations.

Combination Relay

In industrial control, the user is more often interested in open phase and phase reversal protection than in phase unbalance. (Phase unbalance is normally a switchgear distribution problem.) Current operated industrial relays are available which combine both functions.

6. GROUND FAULT PROTECTION

The purpose of ground fault protection is to detect and initiate tripping of the suitable power interrupting switch to clear the ground fault in the event of a grounded phase conductor. Ground fault protective equipment supplied in the motor controller will operate on grounds occuring on the load side of the controller current transformers. The equipment will be inoperative on any grounds occuring on the line side of the controller. The tripping of the power supply circuit is initiated in order to minimize fault damage and to protect the power system.

The line switch in motor controllers can be used for ground fault interruption, providing the available fault currents are limited within the interrupting capacity of the line switches. Normally on a wye system, current limiting resistors or reactors are employed in the neutral ground connection to limit the fault current to a safe value. Should the available ground fault current be in excess of the interrupting capacity of the controller line switch, the ground fault protective equipment should be connected to trip back up circuit breakers or the ground fault protection can be eliminated and rely upon motor controller high interrupting capacity current limiting fuses when they are provided. Ground fault tripping of motor controller line switches is not recommended for use on ungrounded systems. On such systems, the protection would not operate when the first phase ground occurred, but would operate when the second phase-to-ground should occur resulting in a phase-to-phase fault which normally would be well in excess of the interrupting capacity of the line switches.

There are three circuits for obtaining ground fault protection in motor control equipment. One method referred to as residual tripping (Fig. 9), consists of a sensitive adjustable current relay placed in the neutral grounded connection of the three-current transformer secondary circuit. During normal operation, all three phases being balanced, the zero sequence current in the neutral would be zero, rendering the ground protective relay inoperative. In the event of a phase unbalance which occurs when a ground fault occurs, the unsymmetrical circuit condition causes current to flow in the grounded neutral of the current transformer secondaries which causes the ground fault relay to operate. This type of protection required three current transformers and one current relay.

The residual ground fault relay system normally uses an inverse type induction overcurrent relay to minimize the false tripping tendencies experienced with instantaneous relays (see Fig. 9).

Another method of ground fault protection uses a torroid transformer (Fig. 10). Here, a torroid or doughnut-type current transformer is used, having all three motor load leads running through the center of the current transformer opening. When all three motor leads are carrying equal current, the resultant flux induced into the current transformer is zero. Should a ground fault occur, the unbalance condition produces a resultant flux in the current transformer which causes secondary current to flow to trip a suitable instantaneous overcurrent relay. This type of protective circuit is normally not affected by phase transient conditions and is therefore, less susceptible to false tripping. The circuit requires one suitable torroid current transformer and one overcurrent relay. The torroid-type current transformer is required in addition to the current transformers used for overload protection and metering normally employed in motor controllers. This type of ground fault protection is usually preferred because of its simplicity.

The use of differential current relays also provides ground protection for motor windings. This type of protection can be applied primarily to wye connected motors having six terminals brought out to the therminal box. Six current transformers are required with three placed in the line connections and three placed in the neutral connection. The line and neutral current transformers for each of the three respective phases are connected to corresponding balance coils in the differential current relay. In this way, the current is metered in and out of each phase winding to produce tripping should a discrepancy in current balance occur. This type of protection is the most sensitive and the most expensive, normally, it is not justified on motors, except those having ratings well over 1000 hp.

7. INCOMPLETE SEQUENCE PROTECTION

The purpose of incomplete sequence protection is to protect against malfunctioning of the control circuit. This protection is normally employed to protect components of controllers of major importance which are intermittently rated. Such components might be starting duty resistors, reactors, autotransformers, and so forth. The protection may also be used to insure the proper programming of circuitry required for process operation or control.

Incomplete sequence protection is normally provided through the use of a timing function which is initiated at the instant of motor starting and automatically rendered ineffective by the successful completion of the last step in the cir-

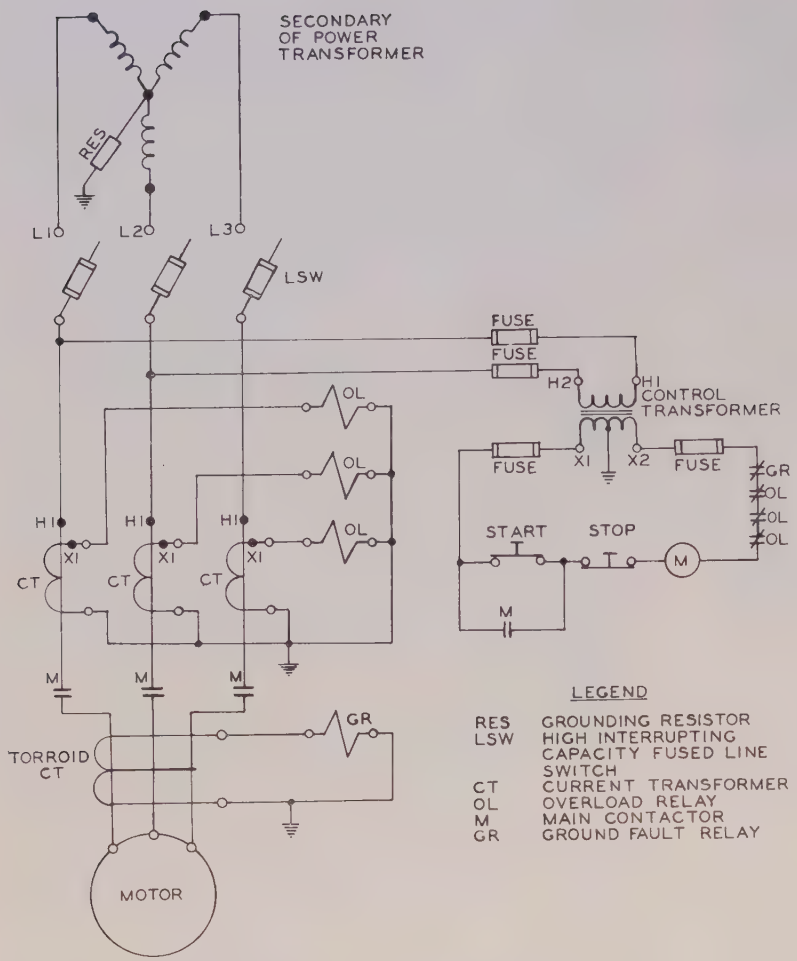


Fig. 10. Full voltage cage controller having torroid current transformer type ground fault protection

cuitry. Should the final step fail to operatewithin its desired limits, the protective element will operate stopping the motor. When incomplete sequence protection is used, to protect components having intermittent thermal ratings, thermal type timing devices having wide range adjustment are normally employed in order to provide protection that follows the actual heating of the components being protected. Thermal protected devices also provide some degree of memory which aids further in protecting components subject to operating heat storage. Protection for programmed circuitry usually employs conventional pneumatic or motor driven timing relays. A typical circuit for providing incomplete sequence protection for a motor starting reactor is shown in Fig. 11.

8. PULL-OUT PROTECTION

Pull-out protection prevents synchronous motors from running out of synchronism on the starting winding, which would be damaged by prolonged operation. Conditions which cause synchronous motors to lose synchronism or pull-out of step are: overloading of the motor, load shocks, line disturbances, low line voltage, and insufficient field current. When the motor pulls out of step, the rotor loses speed, resulting in disturbances being set up in the field and primarycircuits. Relays used to provide pull-out protection are actuated by either the field or line disturbance. The synchronous motor controller diagrammed in Fig. 11 employes a relay that combines the functions of applying the field to the motor at the optimum condition of rotor-stator relationship and removing field excitation on pull-out conditions. These functions are accomplished with relay F.R. when the motor is running at synchronous speed and pull-out occurs. The F.R. current coil is actuated by the resulting disturbance in the field and shuts-down the motor to prevent violent vibrations and line oscillations. Opening of the field contactor energizes the incomplete sequence relay I.S., and squirrel cage protecting relay (S.C.R.). If the condition causing the pull-out is correct before the relays operate, the motor will resynchronize as a normal start. Otherwise the motor will shut-down.

Many large high-speed and most types of low-speed synchronous motors do not have sufficient torque to accelerate and synchronize their full-load capacities. On pull-out conditions these motors could not be resynchronized and would stall if the load were not removed. Where possible, automatic unloaders, such as solenoid valves and clutches, can be utilized to remove the load on pull-out conditions. These devices are usually actuated by the opening and closing of the field contactors. Time delays are sometimes required between the operation to ease the shock of loading. Unloading devices greatly lessen the starting burdens and shocks to the motors. Loading contacts on field contactors on synchronous motor controllers are available at small added cost. If such unloading provisions are not possible, the controllers can be arranged to shutdown the motors instantly under such conditions.

9. LOSS-OF-FIELD PROTECTION

The most likely cause of synchronous motor pull-out is due to insufficient or no field excitation current. Such conditions can be produced by failure of the d.c. exciter, opening of field breakers, fuses, disconnects, loose connections, brush breakage on slip rings, and open field. Protection from loss of field or insufficient field is provided by a current relay connected in series with the synchronous motor field. The relays are normally set to pickup at approximately 75% rated field current. Pull-out protective relays cannot always protect a synchronous operation if the field circuit of the motor becomes open for no transient currents could flow to operate the relay. For this reason, loss-of-field protection is needed as supplementary protection.

Voltage relays may be placed across excitation supplies or across the field connections to obtain protection from loss of field, but will not give complete protection. With an opening in the motor field winding or a brush breakage on the slip rings, voltage would be present at the field terminals but no field current could flow. A current-type relay will detect this condition.

Voltage relays are sometimes used to advantage when separate motor-generator sets are used to supply field excitation. The relays can be connected across the exciter-generator output. They operate when the d.c. voltage is normal and thus permits the motor to start and run.

Current relays and voltage relays for field protection are not standard on synchronous motor controllers but can be easily applied. Loss of field protection providedwith current relays is recommended for all polyphase synchronous motors.

10. STARTING WINDING PROTECTION FOR SYNCHRONOUS MOTORS

Synchronous motors which are self-starting have built-in squirrel cage winding or amortisseur windings which are intermittently rated and requireprotection from overheating. The allowable time at which synchronousmotors can operate at various subsynchronous speeds varies considerably with the design and torque characteristics of the motors. Under

locked-rotor conditions, the allowable operating time for the squirrel cage windings may be from 3 to 20 sec., while the permissible operating times at 95% speed may vary from 1 to several minutes. The permissible operating times for the inbetween speed points vary as an exponential function. Squirrel cage protection is provided on synchronous motors to protect starting windings from overheating at subsynchronous operation. The purpose of this protection is to provide tripping at prolonged operation at any speed point and yet provide sufficient leeway to permit the motors to be successfully started under normal conditions.

Squirrel cage protection is normally provided through the use of thermal relays or relays which have temperature influencing characteristics in order to approach the heating constants and heat storage constants of the starting windings being protected. The protective relays are actuated from a power source obtained from the field discharge circuit during starting in order to obtain a signal which is function of both varying magnitude and frequency with frequency varying from line frequency at locked-rotor to zero at synchronous speed. Discriminating circuits are required in order to obtain continuously variable operating signals for the squirrel cage protective relays in order to match the protection with the motor starting winding thermal capacities. Usually control components such as capacitors, reactors, resistors, magnetic amplifiers, etc., are employed for the operation of the squirrel cage protective relays. Multielement network circuits usually provide a higher degree of matching throughout the acceleration of the motor than do those circuits having only one discriminating element. A typical squirrel cage protective relay circuit is shown in Fig. 11.

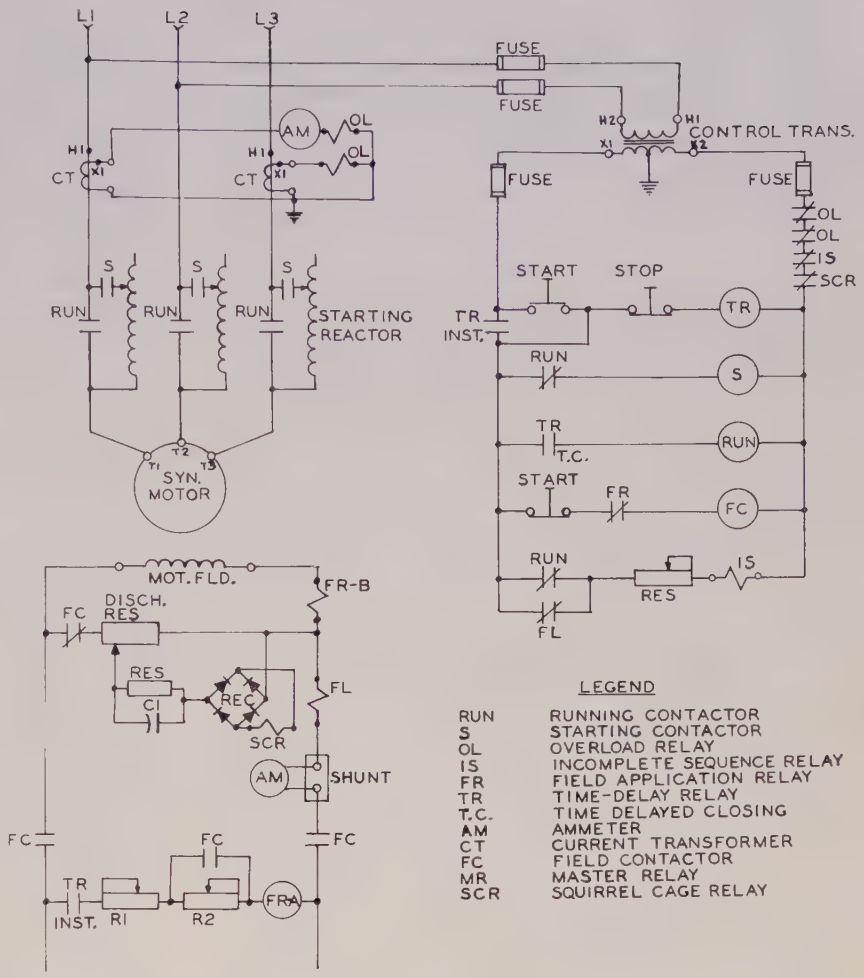


Fig. 11. Reduced voltage reactor type synchronous motor controller having incomplete sequence, squirrel cage and pullout protection

11. EMBEDDED MOTOR TEMPERATURE PROTECTION

Motor stator winding overtemperature protection can be provided by embedding temperature detecting devices within the motor windings. These protective devices may either be direct tripping, remote tripping, or remote indicating. The direct tripping types may be either of the bimetal contact type or may be of the thermister contactless type. The placing of winding temperature protection directly in the motor is a true measure of actual motor winding temperatures but does not provide complete protection under extreme high current conditions such as locked-rotor, a considerable time lag will exist in transferring high heat from the phase conductors through the conductor insulation to the temperature sensing device. This time delay can be sufficiently long to allow serious damage to the phase conductors and insulation adjacent to the conductors. Remotely located overload relays which are responsive to motor current would normally act much faster under this condition to protect the motor. One disadvantage sometimes associated with the embedded temperature protection is the long reset time required for the motor to cool down sufficiently for the protective device to reset allowing the motor to be restarted. This may necessitate a motor shutdown of an hour or more, where otherwise, with conventional overload relays, the motor could be restarted after a few minutes and operated unloaded in order to accelerate cooling through the internal cooling system of the motor until safe operating temperatures are again reached. A combination of conventional current operated overload relays and embedded temperature protected devices when properly coordinated, appear to provide the optimum motor insulation overtemperature protection. Such devices are recommended for motors subjected to highly fluctuating loading.

12. INSULATION PROTECTION

In addition to excessive temperature, conditions such as excessive moisture or voltage surges can also cause instantaneous insulation breakdown. Motors are protected from moisture condensing on winding insulation by heating elements called "space heaters" that are placed inside the motor enclosure and are normally energized only when the motor is shutdown. The heaters are usually energized and deenergized by the motor controller. Figure 8b shows a typical arrangement for the operation of motor space heaters.

Normally, space heaters are available on motors above 100 hp. where there is room for mounting the heaters. The temperature inside the motor enclosure must be maintained above the dew point to prevent condensation. Power consumption usually runs about 5% of the motor's full-load losses.

Space heaters can also be installed in the motor controller to protect it from the effect of excessive moisture. The controller heaters are usually operated simultaneously with the motor heaters.

High voltage surges caused by lightning and high-speed line switching can be of sufficient magnitude to breakdown the insulation of the motor stator windings. To protect against these conditions, surge capacitors and lightning arresters are connected in parallel with the motor phases. These devices can be located at the motor terminals or in the motor controllers. Surge capacitors are normally required on motors rated at 2000 v. and above.

CONCLUSION

From this discussion it can be seen that there are many problems in connection with the control and protection of electric motors, especially those of large size. Some of these problems have been briefly outlined and from the solutions given, it can be seen that very often it is difficult to obtain complete protection of all types and, at the same time, assure the best operation of the motor. Sometimes a compromise is necessary and some desirable function or functions must be eliminated to get best all-around performance.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

Rubber Roll Maintenance

PAUL J. MITCHELL and WILLIAM H. MORDO

This paper is a general discussion concerned with the conditions that affect the life and maintenance of rubber rolls. Suggestions are given for their proper care.

Rubber roll cracking, corrugating, ridging, and unusual wear are known to most of you, and these are problems affecting the cost of maintenance.

To understand what happens to cause these conditions, we must understand some of the physical properties or behavior of rubber and mechanical conditions that can influence the maintenance cost.

Rubber is a noncompressible material, which means when it is subjected to pressure it is displaced and forced to assume a different shape. In a paper machine, the rubber, as it passes through the nip, must yield and distort to meet the mechanical conditions imposed at the nip and then return quickly to its original shape to be ready for another trip through the nip.

Rubber is an elastic material, but not completely so, and although it has high resilience and recovers very rapidly, there can be mechanically induced deformation so great that permanent distortion does take place.

This can be observed at times on a rubber covering as corrugations parallel with the axis of the roll or as abnormal wear patterns. These abnormal wear patterns can be measured by calipering the crown on the roll as removed from the machine and comparing this profile to the crown which was originally ground in the covering. We can then visually see the effects of pressure, speed, and load distribution and the shape the rubber has assumed from mechanical conditions in the operation of the roll.

Frequently, there are times when the balance between crown and load are not kept consistent. This creates a condition where the load distribution on the rubber cover is not uniform. The rubber then exhibits another of its physical properties, that of plastic flow or "creep."

When the load distribution is uneven, the creep property will become apparent as the rubber under the greatest stress will try to move away from the high stress area toward the area of lesser load. This can be observed visually on the rubber cover as circumferential ridges, and in particularly severe operations as a buildup of rubber near the edges of the roll or adjacent to an end relief.

As this condition develops, the load distribution also changes until a condition of high and low pressure is side by side, and localized stress becomes greater than the ability of the rubber to bear. Cracking, shearing, and ultimately complete failure will result.

First let us discuss corrugation and ridging. These are formed on the rubber because of stress conditions such as too much load for the rubber thickness and the rubber hardness. Under high loads with soft covers, rubber cannot resist the excessive movement in the surface and permanent deformation results. The rubber has been forced to assume a different shape. The important thing to remember here when regrinding is done, is to refinish the roll, being sure to remove all of the distressed surface and get below the affected area. The stresses which hold the rubber in the deformed shape must be eliminated completely by grinding well below the low areas. If this is not done well and they are only partially ground out, the rubber will attempt to recover the shape it originally had before being stressed.

Running in the machine and mechanically working the cover accelerates the recovery, but if the stresses have not been completely removed what happens now is the former low areas, as they recover, become raised above the completely stressed, relieved, former raised areas. The corrugation appears again in a very short time. This can be an expensive problem in time and loss of cover life through frequent regrindings. Ultimately, the cover will be reduced in thickness enough so that there is less movement and distortion under load and corrugation will stop. But there are ways to prevent this type of thing from happening in the first place.

These then are some of the severe conditions which lead to excessive maintenance, both in time consumed, and loss of valuable cover thickness.

Of the first importance is the proper distribution of load in as uniform a manner as possible. If the pressure applied is evenly distributed across the face of the rubber roll, the ability of the rubber to withstand that load is increased. This brings us to the subject of proper crown-load balance.

There are many factors that influence load distribution, the most important being the normal deflection of the metal body under load. This is compensated for by crowning the roll so that as the load is applied and the deflection occurs, the pressure is distributed evenly across the full contact area.

The amount of crown required is directly related to the load applied. A change in one requires an adjustment in the other if abnormal conditions on the rubber cover are to be avoided.

A straightforward theoretical approach to proper crowning based on the deflection of the roll body under a specific load is definitely essential, but does not take into consideration the load deflection properties of the rubber covering itself, which does influence also the need for crown.

This factor *can* be reduced to a mathematical function for a given rubber compound and a specific hardness, but is constantly changing because the physical properties of the rubber are such that they are changing steadily.

There are several simple tests that can be made in the machine to determine the proper crown, or to refine the crown for better roll life.

A nip impression made with carbon paper will allow for a visual examination of the contact area and when properly interpreted, some adjustments can be made.

A nip impression with embossed aluminum foil will bring out more detail of the contact area, and when several are made with varying loadings, the crown-load balance can be established very quickly.

And last, tests can be made with Niptronic or electronic equipment which will accurately determine exactly what load matches the crown on any particular press.

P. J. Mitchell and W. H. Mordo, Stowe-Woodward, Inc., Griffen, Ga. and Newton Upper Falls, Mass., respectively.

This particular type of study will give the most benefits in extending overall roll life, increase the intervals between maintenance grindings, and reduce the time and amount of material removed during each maintenance grinding.

Another method of saving time and reducing costs in the maintenance of rubber rolls is to have a routine visual inspection of each roll whenever the machine is down. It takes very little time and may save down time on the machine. This inspection should note the general condition of each roll, and more important, find those with unusual conditions. If it is noted a covering is showing signs of distress, such as cracking, or checking, it will be far less costly to ready the spare and schedule a shutdown for roll change rather than to just run along until the roll will no longer operate.

The time required to regrind to remove all the checking will be reduced and amount of material removed will be less.

Unusual conditions of wear and distress on rubber rolls are produced from mechanical conditions in the operation, and it is extremely rare when they are inherent in the covering itself, although this is the first thought expressed. If an investigation of any unusual condition is made when the condition is first noted during a routine inspection, generally a mechanical adjustment then will save the cost of many expensive rubber coverings.

Many mills operate on a rigid schedule of routine maintenance regrinding for their rubber rolls, and this is one of the surest ways for saving time and reducing costs. Less time is required for maintenance, less rubber loss is achieved, the spares are always ready and available in case of accident, and all rolls are always in good condition.

For instance, it has been established in many mills that with planned or required maintenance schedules of regrinding, the life span of a size press roll has been increased, the operation of the roll has been far more efficient, the quality of the sizing improved, and a complete absence of problems has resulted.

In heavy duty operations such as Yankee pressure rolls or breaker stack rolls, the regular inspection, coupled with scheduled maintenance, will definitely reduce costs. In most of these cases if a further step is made to study crown and load distribution, the benefits are also derived as an increase in running time between grindings.

One of the best ways to improve the life of rubber rolls and reduce costs of maintenance is to keep accurate records of the roll condition as removed from the machine included in the service record of each individual roll. These records often lead to corrective changes in press operation for better life and point out these areas where chronic troubles exist. No one can remember the details of roll operation, but a complete service record will show details.

Tying into the subject of records on rolls, is the maintenance and storage of such rolls. This subject is one which cannot be stressed too strongly to mill personnel. Experience has proved that by following the recommendations of your rubber roll supplier, one cannot help but benefit by longer life and better quality.

Most mills have their own grinding equipment and have had enough experience to know how a roll should be ground. However, we feel that there are a few factors that are most frequently overlooked and should be brought to light.

When a roll has been in storage for any appreciable length of time, the surface characteristics can change and some oxidation usually sets in. A certain percentage of creep or sag in the rubber takes place, and all this is normal. It is therefore strongly recommended that rolls be reground just prior to installation, rather than immediately after removal from the machine. This insures a fresh rubber and perfectly concentric surface for startup. It should be remembered also that on routine regrinding, at least $^1/_{16}$ in. on the diameter should be removed. Too often mills make the mistake of trying to skimp and save rubber by merely cleaning up the surface with a very light cut. Many times checking or gouges are not entirely eliminated, and these eventually work into longer and deeper cuts once the surface has opened.

Dubbing or relieving the ends can be beneficial to rubber coverings in certain cases. A dub will allow the pressure to be relieved, and is a type of prevention against end cracking.

When "special" finishes are desired, such as for coating rolls, your rubber company would be most willing to pass along suggestions based on experience.

Some mills try to use an all-purpose grinding wheel for grinding metal and rubber rolls. This is not recommended and best results can be obtained on rubber coverings when the wheel suggested by your rubber roll manufacturer is used. Either wet or dry grinding will give good results.

When a roll is received at the mill, it is suggested that it be inspected right away. This assures you that the roll has been received in good condition and is ready for installation. Don't wait to inspect the roll just prior to installation in the machine.

Rolls should be stored in a cool, dark place, 60 to 70°. If possible, cover the surface with a wet felt or burlap. Do not expose rolls to sunlight to extreme changes in temperature. A roll should never be brought in from a cold area and immediately installed and operated. Always allow the roll to come to room temperature before operating. Rubber will freeze, and if run under this condition, will crack very rapidly.

Always protect the surface from oil drippings or exposure to grease as this can cause swelling and softening. It is wise to leave the protective paper on the roll as received, as this is usually reinforced. Rolls should always be supported on the journals. Whenever a roll has to be moved to another location by means of a truck or dolly instead of a crane, it is best to use a saddle that fits the contour of the roll. Do not leave the roll resting in this position too long or a rubber set might take place which will necessitate a regrind.

In concluding, paper mills have their individual problems and compromises which they must make for the most efficient operation. Your rubber roll builder has tried to give you a covering which will work best in your operation. However, if for any reason you have to alter your conditions, it is recommended that you consult your manufacturer of roll coverings on changes which could affect your rolls. He is not a papermaker, but he does know rubber rolls, and he will be able to help you.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

Structural Board Machine Power Data

Interim Report—Project No. 621

M. H. FISHER

A preliminary report on the electrical drive equipment for structural board machines, giving the present data, is presented.

In November, 1956, the No. 621 project was started by the TAPPI Electrical Engineering Committee. The suppliers of the electrical drive equipment had noted a wide variation in the power specified for the various sections of structural board making machines and felt that a more unified approach could be made. TAPPI Headquarters invited 20 board manufacturers to participate in the project by supplying data. By October, 1959, seven mills had completed questionnaires covering 14 different machines. Several machine configurations were represented including

M. H. Fisher, Chairman, Project No. 621, Westinghouse Electric Corp., East Pittsburgh, Pa.

Table I. Guide to Selection of Motor Sizes for Structural Board Machines

Tentative and unapproved

	(RDC)						NRL
Oliver Former							
Drum	0.15						
Agitators (each)	0.015						
Table rolls	0.02						
Total forming section	...			...			0 2
Fourdrinier							
	Press no.						
	1	2	3	4	5	6	
6 Press machine	0.05	0.05	0.05	0.1	0.15	0.2	0.35
5 Press machine	0.05	0.05	0.05	0.15	0.25	...	0.35
4 Press machine	0.05	0.05	0.15	0.25	...	...	0.35
3 Press machine	0.13	0.13	0.25	...	...	...	0.35
1 Press machine	0.5	...	...	...	...	...	0.35
Rota-belt (each)	0.035	...	...	...	...	...	Included
Cut-off saw	0.035	...	...	...	...	...	0.025
Dryer feed	0.075	...	...	...	...	...	0.05
Tipple	0.09	...	...	...	...	...	0.06

RDC—recommended drive constant—hp./in. width/100 f.p.m. NRL—normal running load—hp./in. width/100 f.p.m.

Oliver formers and fourdriniers with varying numbers of driven press rolls.

The limited data supplied and variations in machine configuration resulted in insufficient data to be conclusive in formulating a TAPPI Data Sheet. Also, loading practice varied widely and may have been dictated by the capacity of the installed motors, therefore, the No. 621 Committee suggests that a "Guide to the Selection of Motor Sizes for Structural Board Machines" be published for trial use by the users, machinery manufacturers, and electric drive manufacturers. If, after several years' use, additional data and/or successful use of the data have been experienced, then a data sheet can be issued.

Included with this preliminary report is a tentative and unapproved copy of the "Guide to the Selection of Motor Sizes for Structural Board Machines." Selection of constants for the Oliver former, cut-off saw, drier feed, and tipple was straightforward based on the data received. Selection of press constants was made through use of the data collected and a logical approach to the application. Since the fourdrinier wire at the last press takes nearly 180° wrap on the roll, it is capable of transmitting considerably more torque than the other presses which make only nip contact. Also, as the wet fibers are pressed down, greater pressure and better contact are achieved. Thus, greater torque can be exerted. When most of the presses are driven, the drive nearest the headbox will be adjusted so that only the torque required to furnish the losses of the roll itself will be supplied. Thus, when a large number of press rolls are driven, those nearest the headbox can be rated identically.

A complete report containing the data from which the attached guide sheet was prepared will be issued in the near future to the Electrical Engineering Committee and to several authorities in the industry for their comments, criticisms, suggestions.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct 24–28, 1960.

Selection of Refiner Motors

Project No. 852

C. G. HERRINGTON

This paper is limited to general purpose applications involving motors flexibly coupled to centrifugal pumps, motors, agitators, vacuum pumps, etc. In general purpose direct flexibly connected service, expected loading is really very light and thus expected loading is not the immediate cause of premature bearing failure. General purpose sleeve bearing motors are capable of carrying momentary thrust at best. Thrust on the bearings of sleeve bearing motors can result from improperly designed and maintained driven equipment, from motor shafts not being level, and from misaligned flexible couplings of certain types. Motor bearing thrust can be eliminated by proper design and maintenance of driven equipment, by absolute level of motor shaft, and by use of limited end float modifications of the free floating type couplings. NEMA Motor and Generator Standards Publication is applicable to a broad line of equipment used in pulp and paper mills.

C. G. Herrington, The Buckeye Cellulose Corp., Foley, Fla.

Since many of us are occasionally faced with the responsibility of specifying and selecting motors for refiners, TAPPI Project No. 852 was initiated to develop sufficient guides to permit proper selections. This account is to outline the scope of the project and to serve as an interim report.

Motor types, torques, bearings, enclosures, and accessories are being investigated to insure the most economical selections. These characterisics are discussed briefly as follows.

MOTOR TYPES

Although both squirrel cage induction and synchronous motors are suitable for refiner drives, the areas of preference for each appear to be as follows:

1. In the larger ratings synchronous motors are generally used on disk refiners utilizing partial motors since their larger air gaps permit greater tolerances in mechanical assembly in addition to providing better efficiency and power factor.

2. For ratings 250 hp. and greater at speeds of 514 r.p.m. or less, for ratings 500 hp. and greater at speeds up through 1200 r.p.m., and where ratings exceed 1 hp. per r.p.m., consideration of unity power factor synchronous motors is recommended.

When leading kva. is desired for good system operation, use of 0.8 power factor synchronous motors at premiums up to 20% over unity power factor motors should be compared with the use of shunt capacitors to insure the greatest return on invested capital. If greater than normal motor torques are required, the lower premium of such torques for 0.8 power factor motors should be included in such a comparsion.

TORQUES

The capacity of normal torque squirrel-cage induction motors has been found to be adequate for refiner applications.

With synchronous motors it is current practice to specify motor torques of 50% starting, 50% pull-in, and 150% pull-out for conical refiners and 60% starting, 60% pull-in, and 150% pull-out for disk refiners. The starting capacity of conical refiner motors having such torques has been found to be inadequate where mills shutdown and startup with stock in the refiners and where mills attempt to re-start with stock in after an enforced shutdown due to power failures or overloads. The Black-Clawson Co. has a testing program underway to determine the torque requirements of conical refiners with air, water, and 4% stock in the machines. The results of this program will be used as a basis of our final report. Although we presently have no reason to question the adequacy of the above torques for disk refiners, these too are under investigation. For your information the premiums for synchronous motors having greater than normal torques are as follows.

R.p.m.	50% Starting and pull-in, 1.0 pf.	50% Starting and pull-in, 0.8 pf.	100% Starting and pull-in, 1.0 pf.	100% Starting and pull-in, 0.8 pf.
514–1800	0%	0%	15%	11%
450 and below	6%	3%	26%	20%

BEARINGS

Both ball and sleeve bearings are satisfactory; however, where telescopic type couplings are required the bearings must be capable of withstanding end thrust. This subject is under study by the Motors and Generators Subcommittee and their findings will be included in our final report. The following formula has been generally used to determine the continuous thrust when using gear type couplings:

$$\text{Continuous thrust, lb.} = \frac{630 \times \text{hp.}}{\text{Coupling size} \times \text{r.p.m.}}$$

The momentary thrust developed during positioning of the plug is considered to be approximately 20 times as great. Sleeve bearings having end thrust capacities of 500 lb. continuous, 1500 lb. momentary for motors rated less than 1 hp. per r.p.m. or 1500 lb. continuous, 5000 lb. momentary for motors rated 1 hp. per r.p.m. and greater can be obtained for a 3% premium. Ball bearings having similar thrust capacities can be obtained for a 5% premium. As sleeve bearings are standard in the larger motor ratings, the actual premium for ball bearings is 2% where end thrust capacity is required.

ENCLOSURES

Although splashproof construction has been generally preferred in the past, premiums up to 20% for such construction over that of dripproof do not appear to be justified in view of today's improved insulation systems.

ACCESSORIES

Ammeters or wattmeters are required for load indication to permit uniform refining and to prevent inadvertent overloading. When various amounts of refining are to be performed and where accurate repeatability of settings is desired, wattmeters are preferred. The approximate cost comparisons of indicating and recording instruments are as follows:

Ammeters		Wattmeters	
Indicating	Recording	Indicating	Recording
100%	250%	300%	350%

Motor horsepower and revolutions per minute have not been included in the characteristics under study as these depend on the kind of tackle used, type and flow of stock, and the amount of work to be done and should be determined in conjunction with the refiner manufacturer.

This project is still in the development stages; consequently, any comments or suggestions that any of you may have will be appreciated as these will enable us to produce a more useful report.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

Current Status of Alkaline Digester Corrosion as Reported by Regional Digester Group

JACOB B. MORRISON, H. M. CANAVAN, and ZANE S. BLANCHARD

This paper, the fifth report of Regional Digester Activity, summarizes and evalutes some of the corrosion data that has been received from the various mills participating in the regional program. It also includes comments that were received from 10 mills that reported using stainless steel overlay welding in 67 digesters to retard corrosion and to extend the useful life of their existing digesters.

In preparing this fifth report covering Regional Digester Activity, TAPPI Mill Report Forms from 22 mills were used, which included 206 carbon steel, stainless steel, and Inconel, lined or clad, digesters.

Reports were received covering 172 carbon steel digesters and 34 stainless steel and Inconel lined or clad digesters. The corrosion rates found in the current data correspond closely with those reported in previous studies.

Table I shows the average current corrosion rate and average corrosion rate in the critical area of carbon steel digesters for individual mills. Tables II and III provide the same information for Inconel and stainless steel lined or clad digesters.

The supporting corrosion data contained in questions 14 through 27, inclusive, of the Mill Report Forms was summarized as follows:

Question 14: Location of critical area?

	Upper shell, %	Middle shell, %	Lower shell, %	Top head, %	Bottom head, %	No critical area, %
1959	45.1	36.3	3.6	3.6	8.3	3.1
1958	31.9	28.4	8.62	7.1	7.1	5.6
1957	23.4	37.3	18.9	5.0	9.4	6.0
1956	36.5	40.9	7.6	2.5	3.1	9.4
1955	23.9	53.1	5.2	9.5	2.3	...

Question 15: Has critical area moved since last inspection?

	Yes, %	No, %
1959	27.0	73.0
1958	17.8	82.2
1957	20.7	79.3
1956	22.8	77.2
1955	14.8	85.2

Question 18: Method of estimation used: numerical—22 mills or 95.6%; graphical—none.

Jacob B. Morrison, Crucible Steel Co., Pittsburgh, Pa.; H. M. Canavan, Chief Inspector, Mutual Boiler and Machinery Insurance Co., Waltham, Mass.; and Zane S. Blanchard, Division Manager, Portland Overlay Welding Div., Chicago Bridge & Iron Co., Portland, Me.

Question 19: Has the average current corrosion rate changed since last inspection?

	Decreased, %	Increased, %	No change, %	Don't know, %
1959	31.6	32.2	16.1	20.1
1958	24.3	28.9	19.8	27.0
1957	40.7	17.5	21.7	20.1
1956	33.1	31.8	26.3	8.8
1955	26.7	44.6	13.9	14.8

Question 21: Has the current corrosion rate at the critical area changed since last inspection?

	Decreased, %	Increased, %	No change, %	Don't know, %
1959	15.6	9.2	58.2	17.0
1958	11.1	1.01	50.8	37.09
1957	5.3	7.9	76.3	10.5
1956	7.3	12.6	72.2	7.9
1955	10.1	10.1	63.6	16.2

Table I. Current Corrosion Rates for Digesters Carbon Steel

Mill code	Number of digesters	Mill average corrosion rate, mils/yr.	Mill average corrosion rate critical area, mils/yr.
A	10	28.6	63.6
B	5	3.4	14.4
C	14	8.5	[a]
D	no reports	...	....
E	14	52.8	66.5
F	8	88.8	105.1
G	2	35.0	[a]
GL	5	26.2	46.6
H	6	17.8	54.9
HL	4	69.2	59.5
I	5	12.2	44.2
J	no reports	...	...
K	4	54.8	68.3
KL	no reports	...	...
L	4	47.7	126.3
M	3	114.7	202.0
ML	no reports	...	...
N	23	44.1	110.8
O	5	43.5	54.6
P	no reports	...	...
Q	28	36.7	39.3
QL	no reports	...	...
R	8	20.0	90.1
RL	11	27.4	34.2
S	1	33.0	49.0
U	no reports	...	...
V	no reports	...	...
W	no reports	...	...
W1	6	overlayed	overlayed
W2	5	[a]	62.5
X	1	68.0	97.0
Z	no reports	...	...
Total	172		
Weighted average		36.2	81.5

[a] Thickness measurement omitted from report.

Question 23: Is a current change in general corrosion indicated by visual inspection only?

	Decreased, %	Increased, %	No change, %	Don't know, %
1959	30.7	36.2	16.0	17.1
1958	22.3	29.4	20.8	27.5
1957	36.5	26.6	18.2	18.7
1956	37.2	34.4	22.3	6.1
1955	30.4	39.3	15.7	14.6

Table II. Current Corrosion Rates for Digesters Inconel, Lined or Clad

Mill Code	Number of digesters	Mill average corrosion rate mils/yr.	Mill average corrosion rate critical area, mils/yr.
B	1	4.0	5.0
N	5	3.2	7.8
T	6	[a]	[a]
Total	12		
Weighted average		3.3	7.3

[a] Thickness measurement omitted from report.

Table III. Current Corrosion Rates for Digesters Stainless Steel 316 and 347, Lined or Clad

Mill Code	Number of digesters	Mill average corrosion rate, mils/yr.	Mill average corrosion rate critical area, mils/yr.
B	2	6.5	5.0
N	1	14.0	[a]
O	1	24.2	27.7
S	8	2.7	3.6
T	3	[a]	[a]
W2	4	[a]	10.0
Y	3	[a]	[a]
Total	22		
Weighted average		6.1	6.7

[a] Thickness measurement omitted from report.

Question 24: Is a current change in localized attack indicated by visual inspection only?

	Decreased, %	Increased, %	No change, %	Don't know, %
1959	16.6	11.5	56.1	15.8
1958	9.18	7.1	50.1	33.62
1957	4.5	12.5	73.0	10.0
1956	10.6	8.6	74.8	6.0
1955	4.0	7.1	75.8	13.1

Question 26: Location of unscaled areas?

	Upper shell, %	Middle shell, %	Lower shell, %	Top head, %	Bottom head, %
1959	24.0	19.9	17.6	16.3	22.2
1958	58.3	41.6	31.0	56.2	58.8
1957	18.1	24.0	18.5	19.8	19.6
1956	21.8	20.5	11.2	23.4	23.1
1955	18.9	22.7	17.3	21.2	19.9

Question 27: Changes made since last inspection which might affect corrosion rate: (1) the use of weld overlay.

Table IV

Mill code	Material used	Length of service, months	Did corrosion rate change?	Did cracking occur?	Are results satisfactory?	Did corrosion rate adjacent to base metal change?	Area covered, sq. ft.
A	310 SS	2–36	Decreased	Yes	Partially	Increased	9–260
C	310 SS	14–61	Decreased	Yes	Yes	Decreased	30–565
H	310 SS	14–17	Decreased	No	Yes	No change	710
HL	310 SS	18–24	Don't know	No	No	No change	655–728
L	Carbon steel	8	Decreased	No	Yes	Increased	80–200
Q	310 SS	0–48	Decreased	No	Yes	Decreased or no change	11–415
RL	310 SS	41	Decreased	No	No comment	No change	85
S	316 LC	18–22	No	No	Yes	No change	14
	Inco-Weld "A"	...	No data yet	No	Yes	Don't know	1
	310 SS	6	No change	No	Yes	No change	2
W1	316 SS	16–20	No coment	No	...	No change	1750
W2	310 SS	36	Decreased	No	No	No comment	1330

(2) raised cooking temperature 20°, (3) increased number of cooks and production, (4) increased rate of cooks, and (5) changed location of steam and liquor nozzles.

The cause of corrosion in the critical area was summarized as follows:

	1959, %	*1958, %*	*1957, %*	*1956, %*
Liquor charging	44.0	24.4	23.9	30.1
Liquor circulating	8.5	6.6	15.3	15.5
Normal corrosion	none	12.2	9.4	10.3
Chip impingement	2.5	none	10.2	8.2
Chip contour	none	none	3.9	7.3
All other causes	14.0	14.2	6.3	11.8
Don't know	31.0	43.5	31.0	16.8

The average current corrosion rate for 172 carbon steel digesters ranged from 3.4 to 114.7 mils per year, as compared with 2.2 to 100 mils per year in 1958. The average corrosion rate in the critical area ranged from 14.4 to 202 mils per year, as compared with 1.5 to 260 mils per year in 1958.

Reports covering 12 Inconel lined or clad digesters were reviewed, but due to lack of information it was only possible to establish corrosion rates on six digesters. The mill average corrosion rate ranged from 3.2 to 4 mils per year, with a weighted average of 3.3 mils per year. Reports covering 22 stainless steel lined or clad digesters were studied, but due to insufficient information the corrosion rates had to be based on 12 digesters. The mill average current corrosion rate ranged from 2.7 to 24.2 mils, with a weighted average of 6.1 mils.

The critical area in the carbon steel digesters was located in the upper shell in 45.1% of the digesters and in the middle shell in 36.3% of the digesters. It appears the critical area is now located in the upper shell as compared with the middle shell for several years. In 73% of the digesters the critical area has not moved as compared with 82.2% in 1958.

OVERLAY WELDING

Ten (10) mills reported using overlay welding in 67 digesters to retard corrosion and to extend the useful life of existing digesters. This is an increase of approximately 10% over the digesters recorded in 1958. The approximate areas covered varied from 1 to 1750 sq. ft. or the entire shell section of some of the digesters.

The overlay was located as follows:

	Upper shell, %	*Middle shell, %*	*Lower shell, %*	*Top head, %*	*Bottom head, %*	*Critical area, %*
1959	52.3	47.8	37.4	10.5	53.7	13.4
1958	29.5	32.8	42.5	none	42.5	18.1

Table IV shows the overlay welding which has been carried out and the comments received from the mills.

The mills reported as follows:

1959	61.2% reported no cracking, while 32.9% had trouble with cracking.
1958	95.0% reported no cracking, while 4.9% had trouble with cracking.
1959	62.7% reported the corrosion rate decreased, while 12.0% did not know.
1958	54.0% reported the corrosion rate decreased, while 27.4% did not know.
1959	56.7% reported the overlay as satisfactory, while 32.8% reported they were having some trouble with it.
1958	65.5% reported the overlay as satisfactory, while 6.5% reported they were having some trouble with it.

Where areas were overlayed did the corrosion rate of the parent metal adjacent to the overlay change?

	Increased, %	*Decreased, %*	*No change. %*
1959	16.4	23.9	41.8
1958	29.4	4.9	...

SUMMARY

The following conclusions are based on the data submitted:

1. The average current corrosion rate for carbon steel digesters, based on the weighted average, has increased from 28.2 to 36.2 mils per year.

2. The average current corrosion rate in the critical area of carbon steel digesters, based on the weighted average, has increased from 69.1 to 81.5 mils per year.

3. The critical area appears to remain in the upper shell, while the percentage of mills reporting the critical area in the middle shell has increased from 28.4 to 36.3%.

4. It appears liquor charging is still leading the list of causes for corrosion in the critical area. However, a large number of mills are still reporting that they do not know the cause of the corrosion in the critical area. It appears that if this percentage could be further decreased we would have a better balance as to the cause of the corrosion in the questionable areas.

5. It is interesting to note that the average corrosion rate for all carbon steel digesters, based on the weighted average, is 36.2 mils as compared with 3.3 mils for the Inconel lined and clad digesters and 6.1 mils for stainless. The average corrosion rate for the critical area for all carbon steel digesters, based on the weighted average, is 81.5 mils as compared with 7.3 mils for Inconel lined and clad digesters and 6.7 mils for stainless.

6. Overlaying of carbon steel digesters with stainless steel has generally proved to be a valuable tool for increasing the service life. Unfortunately, there have been some failures after limited service.

A panel, representing the industry, insurance underwriters, inspectors, installers of overlay and technical services, was available at the 14th Engineering Conference in Pittsburgh to discuss various phases of this subject. It was hoped that the discussion would develop sufficient data to permit the Corrosion Committee to prepare a specification which would enable the mills to guard against faulty installations and to secure overlay which would give trouble-free, long service life. It is expected that the Corrosion Committee will eventually develop minimum specifications for this type of work.

There is a lot of activity among technical experts to try to determine why failures occurred in some cases while in similar cases the overlay was performing satisfactorily. At this date everything points its finger towards the method of application. This involves the rate of travel, the material deposited per square foot and the richness of the alloy as deposited or the percentage of dilution. Once a standard specification has been established one would expect that most of the serious difficulties would be eliminated. However, overlay is not a cure-all and will require some maintenance.

Information received shows that 61.2% of the mills were only having minor problems with cracking in the overlay that they installed, while 56% reported the overlay was performing satisfactorily.

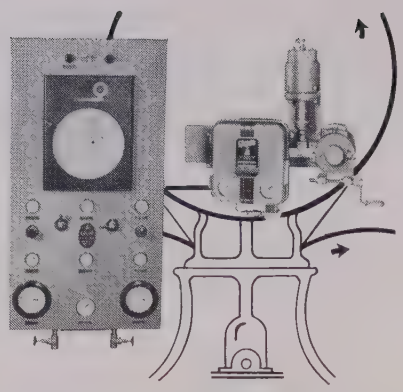
The excellent response from the contributing mills and the cooperation and assistance received from the Regional Committee Members are gratefully acknowledged.

Presented at the Fifteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–28, 1960.

Questions and Answers

Good engineering questions are solicited as well as answers or alternate answers to the published questions. Material should be sent to TAPPI Headquarters, marked for the attention of H. O. Teeple. The items contributed will be forwarded to the Question and Answer Committee for processing. If comments are to be contributed, please refer to the question number.

You don't need an electronic technician to run this moisture control system



It's the most simple, trouble-free system ever built . . . yet it maintains any moisture content desired in any weight of paper

The Stickle Pres-ten-trol uses the time-tested, mill-proven principle of sheet expansion and contraction to regulate steam flow to the dryers . . . for any weight of paper from .0003 to the heaviest board. It provides instant regulation with minimum fluctuation . . . records moisture variation, steam pressure in dryers, time and duration of wet end breaks . . . holds steam pressure desired when paper is off the machine. On a recent 24-hour test, moisture content varied only 3/10 of 1%. Yet, no other system costs so little to buy, install, operate and maintain, because no other is so simple, so trouble-free. Write for Bulletin 460-C.

STICKLE STEAM SPECIALTIES CO.
2209 Valley Avenue
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Stickle Equipment
Cuts the cost of steam

(1-3/61) *Question:* **How can the amount of sodium sulfite required be estimated with a deaerating heater having a standard O_2 guarantee of 0.005 cc. per liter?**

(*1.1-3/61*) *Answer:* 0.005 cc. per liter equals 0.0067 p.p.m. Sulfite requirement is approximately 10 lb. sodium sulfite to 1 lb. of oxygen.

(2-3/61) *Question:* **As applied to mechanical drive turbine governors, what is meant by "deadband"?**

(*2.1-3/61*) *Answer:* "Deadband" is the total speed change within which no measurable governor valve position change takes place.

(3-3/61) *Question:* **What is meant by an isochronous governor?**

(*3.1-3/61*) *Answer:* An isochronous governor controls for constant speed, usually through the use of a reset mechanism which compensate for changes in load.

(4-3/61) *Question:* **How can I tell from the attached chart on my 2000 kw. condensing extraction turbine the amount of 400 p.s.i.g. steam I must add for each pound of steam extracted at 10 p.s.i.g.?**

(*4.1-3/61*) *Answer:* Only a fraction of a pound of high pressure steam need be added for each pound of low pressure steam extracted.

This can be determined by taking any load point on the curve, subtracting the zero extraction steam flow from the total flow with a given amount of extraction and dividing the difference by the amount of steam extracted.

Example:

Load 700 kw.	
Flow with 10,000 lb. extraction	17,500 lb./hr.
Flow with 0 lb. extraction	12,000 lb./hr.
Difference	5,500 lb./hr.

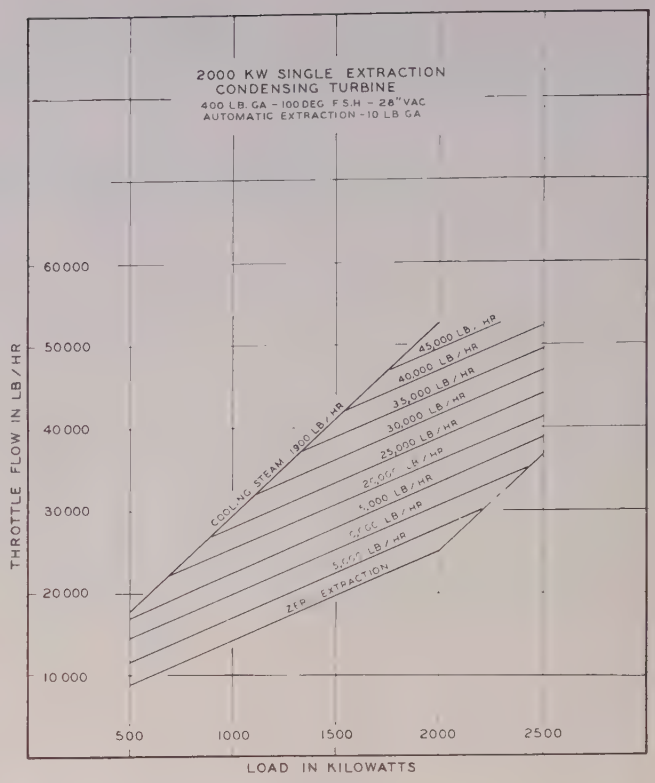

Figure 1

For each pound of 10-lb. steam extracted you must then add

$$\frac{5,500}{10,000} = 0.55 \text{ lb. of 400-lb. steam at the throttle}$$

The extraction performance curves are obtainable from the turbine generator manufacturer.

This information is useful for:

1. Obtaining total flow required for boiler size.
2. For accounting purposes it is often helpful to consider steam costs in terms of steam at the highest pressure.

Example:

If the 400-lb. steam costs 75¢ per 1000 lb. to produce the extraction steam cost is $0.55 \times 75¢ = 41.25¢$ per 1000 lb.

(5-3/61) *Question:* **How much steam can I extract when the electric load is 1000 kw.?**

(*5.1-3/61*) *Answer:* This is determined by going up the 1000 kw., load line to the maximum extraction line at the top of the chart.

The intersection is at a total flow of 29,300 lb. per hour.

The flow at 1000 kw. and 25,000 lb. per hr. extraction is 28,000 lb. per hr.

Difference is 29,300 − 28,000 = 1300 lb. per hr.

$$\frac{1300}{0.55} = 2363 \text{ lb. per hr.}$$

28,000 + 2363 = 30,363 lb. per hr., the maximum amount of steam which may be extracted at 10 p.s.i.g. with a load of 1000 kw.

(6-3/61) *Question:* **Why are the 5000 and 10,000 lb. per hr. extraction lines intersected by another line between the loads of 2000 and 2500 kw.?**

(*6.1-3/61*) *Answer:* Steam flow in this area increases beyond the control of the extraction mechanism in this area and extraction pressure increases beyond 10 p.s.i.g.

RC 295. Degree of Sizing in Paper

The purpose of this method is to provide a means of determining the degree of sizing in a sheet of paper with a Currier size tester.

Equipment

The testing equipment required consists of a Currier size tester, a sample cutter, and a stop watch or other timer graduated in seconds.

Preparing the Sample

Specimens should be chosen and conditioned according to TAPPI specifications, noting, when reporting test results, what the conditioning factors were, and whether felt or wire side was being wetted, or whether results are an average of both felt and wire side. Specimens should not be less than 2 in. square.

Operating Procedure

With the instrument in operating condition and rotary switch in slack size position:

1. Lay a specimen on the plate, "wire" side up.
2. Lower water bottle assembly to the specimen.
3. Starting a timing device the instant the wet felt makes contact with the specimen.
4. Stop the timing device the instant the meter pointer reaches the "end point" marked on the meter dial.
5. Raise water bottle assembly, rest it on short extension on panel at rear of bottom electrode, remove tested specimen and wipe plate dry with a soft absorptive material.
6. If time interval is too long with rotary switch in slack size position, put rotary switch in hard size position and repeat as above.

Those paper impregnated or coated with materials which are conductive, such as carbon black or oxide colors, must be insulated from the plate. Any good "lens" paper may be used for the purpose, provided it contains no polishing compounds. The grid if placed on the plate, under the specimen to be tested. The penetration time for the grid is so short that in the great majority of cases it may be ignored and the time for the test may be reported as for the specimen alone. The grid must be large enough so that no part of the specimen touches the plate.

Reporting

Report the elapsed seconds.

Note: This tester may be purchased from the Thwing-Albert Instrument Co., Philadelphia 44, Pa.

RC 296. Torsion Tearing Resistance of Paper

The purpose of this method is to provide a uniform means of determining the ability of a fiberboard container to withstand rough handling.

Equipment

The equipment necessary to perform these tests is a torsion tear tester, a paper cutter, and a die cutter.

Preparing the Sample

Specimens are cut to a size of $2^1/_4$ in. wide and 5 in. long in the test direction. In order to provide a measure of continued tear rather than initial tear, the specimen is placed in a die cutter and precut with slits at each end to facilitate the start of the tear. At the same time, a circular hole is cut in the center of the specimen to remove that portion which would not have been torn by a 180° rotation of the pendulum. If the torsion tear of a scoreline is to be measured, the scoreline is carefully centered on the specimen's long axis. The specimen is torn in two tears which proceed simultaneously from each end of the test strip toward the center, thus giving the effect of tearing from both sides simultaneously. Specimens of unscored board adjacent to the score area are also torn.

Operating Procedure

In making a test, a prepared test specimen is held between the two clamps which grip it along its full length on each side of the test area through which the tear is to progress.

The energy expended in producing the tear is measured by means of an optical pointer which is rotated by the pendulum shaft. When the pendulum is released with no specimen in the jaws, the maximum energy is a function of the mass of the pendulum and the change in height of the center of gravity. If friction is neglected, the pendulum will swing through 180° if released from the horizontal position. When a specimen is torn, the work expended in tearing the specimen is substracted from the energy in the pendulum system and the pendulum will not swing as far. The difference in angular swing as measured by the optical pointer is then the work done in tearing the specimen and the scale is graduated directly in inch-ounces of work.

Reporting

The higher the energy required to tear the specimen, the greater the resistance to rough handling. This relationship was determined by correlating torsion tear tests with drum and drop tests.

Note: This instrument may be purchased from The Institute of Paper Chemistry, Appleton, Wis.

RC 297. Wax Transfer of Paper

The object of this method is to determine the amount of wax that will be transferred from the surface of paper by pressing between polished aluminum sheets.

Test specimen

Five specimens of the waxed paper, 4 by 8 in.

Apparatus

Humidity cabinet capable of maintaining a temperature of 80°F., with a relative humidity of 90 to 97%. Six polished aluminum sheets 4 by 8 in. by $^1/_8$ in. thick. A 2-lb. weight. An oven maintaining a temperature of 140 ± 2°F.

Procedure

Place specimens in humidity chamber for 4 hr. Lay each sheet between the polished aluminum plates, assemble all plates in one stack. Put stack into oven at 140 ± 2°F. for 24 hr. Remove stack and allow to cool at room temperature for 1 hr. Examine aluminum plates for wax transfer.

REPORTS AND DISCUSSIONS

Presented at National and Regional Conferences

Annotated Bibliography of Mechanical Pulping for 1960

Project No. 932

GILBERT GODIN

To date, 18 articles pertinent to the subject of mechanical pulping for 1960 have appeared in the literature. The subject matter may be conveniently grouped into three classifications: (1) reviews of the various aspects of mechanical pulping technology; (2) design improvements aimed at increasing grinder efficiency and improving pulp quality; among these may be mentioned the use of fast acting cylinders, high load grinding, and the relationship between annual ring width and pulp quality; and (3) new patents, viz. a reinforced pulpstone, a modified stone having internal conduits for water passage, chemical pretreatment of wood before grinding, and a belt grinder for longitudinal grinding. Three articles appearing late in 1959 have been included in the survey.

Brecht, W., "Technological status of mechanical pulp production." *Oslerr. Papier-Ztg.* 65, No. 10: 7, 9, 11, 13; No. 11: 9, 11, 13 (Oct.–Nov., 1959). American and European trends in the manufacture of mechanical pulp (groundwood) are contrasted. The American trend is toward the elimination of grinders and their replacement by chippers and disk refiners. The "coarse grinding plus refining" process is mentioned as a transition between conventional and modern groundwood manufacture. In Europe on the other hand, emphasis is placed on the improvement of conventional grinders and on more basic studies of the grinding process. Factors influencing the manufacture, screening, and bleaching of mechanical pulp are discussed.

Wendshuh, Herbert L., (Appleton Machine Co.). "Ring grinder maintenance influenced by startup and operating methods." *Paper Trade J.* 143, No. 51: 38–40 (Dec. 21, 1959). The discussion centers on the maintenance of the Roberts (gear driven) ring grinder, with outlines given of procedures for starting up and operating the grinder and general maintenance rules, which should be followed for best operations.

TAPPI. Third Mechanical Pulping Conference Papers. *Tappi* 43, No. 1: 188A–252A (January, 1960). The following papers were presented at the Third International Mechanical Pulping Conference held in Quebec City, Sept. 10–12, 1958. Bersano, Piero, "A new grinding method"; Beath, L. R., "A cause of wide uncontrolled freeness variation in groundwood production—the varying angle between stone surface and wood"; Herwig, Guenter, "Effect of groundwood pulp quality on wet and efficiency of a paper machine"; Clark, James d'A., "Fundamentals of groundwood evaluation—a new approach"; Bishop, Fred W., "Advantages of an individual grinder pit testing"; Hoholik, F. S., "Coarse grinding followed by refining"; Hunter, James C., "New wood handling system and groundwood mill at Powell River."

Gilbert Godin, Johns Manville Research Center, Manville, N. J.

Nugent, Joseph, "Groundwood from hardwood chips." *Pulp and Paper* 34, No. 3: 81 (March, 1960); *Pulp and Paper International* 2, No. 3: 26–27 (March, 1960).—A brief description is given of the Bauerite groundwood from chips process which has been installed at three Japanese newsprint mills: Daishowa Paper Mfg. Co., Jujo Paper Mfg. Co., and Tahoku Pulp and Paper Co.

Fischgold, Sulamith, Herscu, Otilia, "Contributions hardwoods." *Celuloză şi hîrtie* 9, No. 1: 9–16 (January, 1960). Results of chemigroundwood pulping trials on an experimental scale, using beech—and poplarwood pretreated with neutral sulfite plus sodium carbonate liquor—are reported. The physical mechanical properties of the pulps obtained were comparable (except for their lower brightness) with those of NSSC pulp and unbleached sulfite softwood pulp.

Jeppson, George, No. Pulpstone Can. pat. 593,529. Filed May 12, 1954, Issued Feb. 23, 1960. Five claims. Assigned to Norton Co. M2399-400. A series of U-shaped clamping members are embedded in the reinforced concrete core of a pulpstone to hold a series of abrasive hexagonal segments having V-shaped bottoms tightly in such relationship that the stone is highly resistant to thermal shock, and cracking of the segments is minimized.

Nestor, Leonard R., and Le Page, Robert A., apparatus for the preparation of fibrous pulp from wood. Can. pat. 594,501. Filed June 29, 1956, Issued March 15, 1960. Two claims. Assigned to Minnesota Mining and Mfg. Co. M2440. Pulpwood billets are ground by a belt-grinding device to produce mechanical pulp. The grinding force is applied to the wood longitudinally, and the fibers produced have a relatively high length: diameter ratio. Paper produced from the pulp is exceptionally strong and opaque, and papers of higher quality than usual can be made.

Vawter, Dale. "Pulp grinder water control." U. S. pat. 2,929,568. Filed April 16, 1957. Issued March 22, 1960. Two claims (CL 241-67) M2447. A pulpwood-grinding wheel having conduits through which water is forced to the outer surface of the wheel is provided with control means which cause water to be forced through any particular conduit only while that conduit is in register with a wood holding pocket of the grinder.

Fields, William F. (Armstrong Cork Co.), "Recent improvements in pulpwood grinders for insulating fiberboard manufacture." *Tappi* 43, No. 4: 202A–207A (April, 1960). A study was made to determine if design improvements could be made to improve the efficiency of the grinders and/or improve pulp uniformity in an installation for the mechanical pulping of loblolly pine. Objectives of the study were: to determine if the surface speed could be increased and if so, to determine the maximum allowable speed; to increase the speed of the pressure foot during nonproductive portions of the grinder cycle (retraction and advancing wood to the stone surface); and to control the pressure foot with regard to feed rates to keep a constant relationship between feed and speed without regard to the resulting variability in hydraulic pressure or motor loading. To accomplish the second and third objectives, it was decided to go to a high pressure hydraulic system so that a small, low volume, fast acting cylinder could be used to actuate the pressure foot. A 50% increase in capacity was effected, which is partly the result of a reduction in reaction

time and partly an increase in grinding rate. The hydraulic control circuit design is outlined in an Appendix.

Luhde, Friedrich. "Groundwood from chemically impregnated and nonimpregnated chips by the Bauerite process." *Wochbl. Papierfabrik.* 88, No. 9: 399–447; No. 10: 379–384 (May 15–31, 1960). Detailed technical information is given on the Bauerite (groundwood from chips) process, including the cold-soda impregnation and subsequent disk refining of hardwood chips, the potentialities of the process (without chemical impregnation) for softwood chips (which is still in the experimental and development stages), the properties of the pulps obtained, and the use of Bauerite pulp for addition to magazine stock and as a partial substitute for normal groundwood.

Schwartz, "Development trends in the technology of grinding." *Zellstoff U. Papier* 8, No. 12: 455–64 (December, 1959). Process and machine technology variables of importance for the quality of mechanical pulp are reviewed and the most fundamental guide rule for the operation of grinders are outlined. High-speed paper machines require the highest possible content of long fibers and a minimum of "mealy stuff." This can be achieved only with single pocket grinders, since all multimagazine grinders entrain fibers from one grinding zone to the next, causing fiber breakage and shortening. A high moisture content of the wood, a high grinding temperature, a pit consistency between 2 and 2.5%, and a water immersion depth of the pulpstone commensurate with its surface condition are mandatory. Dulled stones should be cleaned with water jets of around 5 atm. pressure or with brushing prior to resharpening. Grainage and sharpness of the pulpstone should be adapted to the quality of the wood fiber, using two different sharpening rolls where necessary. Only clarified white water of the paper machine should be used as dilution water. The pulp produced should be checked at least every 3 hr. at the grinders and every 30 min. at the thickener for degree of freeness, shives content, and fibrillation.

Bîrsan, I., "A modern method for the quality control of mechanical wood pulp." *Celuloză şi hîrtie* 9, No. 4: 117–122 (April, 1960). The method is based on the determinations of the dewatering behavior and initial wet strengths of pulp sheets made on the Rapid Köthen sheet former.

Brecht, W., and Berberat, René, "The annual-ring-widths of sprucewood and its effect on the results of the grinding process." *Wochbl. Papierfabrik.* 88, No. 7: 247–249 (April 15, 1960). The density (o.d.) and hence the yield by weight of sprucewood runs through a maximum at an annual-ring width of 2 mm. Sampling of the woodyard of a German pulp mill showed that more spruce logs had this favorable ring width than any other width. Yet, experimental studies indicated that a ring width of *ca.* 3 mm. is more advantageous for the production of a long fibered strong mechanical pulp. Although the pulp yield decreases and the energy demand of the grinders increased with increasing ring width, the sacrifices entailed by using wood of 3 mm. annual ring width are within reasonable limits. For finer, short fibered, and well beaten pulps low in splinters and shives, however, wood of the narrowest possible ring width should be used.

Ceciu, S., and Enescu, Gh., "Determination of optimum grinding and screening conditions for mechanical pulp used in newsprint manufacture at the '1st of September' Paper Mill." *Celuloză şi hîrtie* 9, No. 5: 147–160 (May, 1960). After a theoretical introduction into the fundamentals of grinding and a consideration of wood characteristics (morphology, density, and moisture content) affecting the quality of groundwood, the authors report on experiments carried out at the "1st of September" mill with the goal of establishing optimum grinding conditions for green and dry softwood logs of small and large diameters. It is concluded that high quality mechanical pulp suitable for newsprint manufacture under the prevailing local conditions can be obtained only if logs more than 17 cm. in diameter and containing more than 40% moisture are used. Detailed grinding and screening data are presented.

Voiret, Eugene G., "Manufacture of wood pulp." Can. pat. 598,418. Filed Oct. 30, 1957. Issued May 24, 1960. Eight claims M 2579. A process for pulping wood comprises partially leaching woody material with a liquor containing sodium sulfite, an alkaline hydrosufite, and sodium oxalate and having a pH of 8 to 10, then grinding the woody material.

de Montmorency, W. H., "High-load grinding—exploratory mill experiments employing normal and pitless methods." *Pulp Paper Mag. Can.*, No. 8: T403–T413 (August, 1960). A high load grinding trial limited to a single shift operation, to one stone and pattern is described. Grinding in the load range 0.41 to 1.03 hp. per sq. in. of grinding area was conducted (1) under normal mill conditions of low stone submersion and (2) by a pitless technique. High load grinding increased production rate but yielded acceptable or nearly acceptable pulps only when special conditions known as jamming occurred. This condition was not under full control, but could be initiated by a sharp increase in grinder load. When producing acceptable pulp at high rates under the above condition, the specific energy was unchanged. Pitless grinding presented no operating problems at loads as high as 1.03 hp. per sq. in (2000 kw, per stone). Jamming occurred in pitless grinding at high loads with results similar to those in normal grinding. Pitless grinding differed little from normal grinding regardless of load. The pulps exhibited the same freeness to strength and strength to specific energy relationships. Pitless pulp when compared to normal pulp on a freeness basis contained less long fiber fraction, was less bulky at freenesses just above the newsprint range.

Copeland, W. H., and Perry J. H., "Maintenance of a modern pulpstone." *Pulp Paper Mag. Can.* No. 3: 75–79 (March, 1960). Pulpstone maintenance is discussed in terms of the critical factors of hanging, dressing, starting up of a new stone, and its judicious operation.

Gue, W. M., "Fallacy for grinder motors is neglect; fact is periodic inspection." *Paper Trade J.* 144, No. 25: 26–28 (Aug. 29, 1960). A maintenance-inspection program is outlined for grinder motors.

Paper Trade J. 144, No. 37: 54–55 (Sept. 12, 1960). Two men, eight grinders produce 280 tons of groundwood daily. The automatic grinder room wood handling system at the Ortviken groundwood mill of Svenska Cellulosa A. B. is described.

Progress in Pulp Bleaching

Pulp Bleaching Conference

Chicago, Ill., June 14–16, 1960

Dr. Kraft: Gentlemen. It is with great pleasure that I welcome you to the seventh session. This session will be special in nature and will be special in personnel. Very frequently during our discussions we have heard the name "The Institute of Paper Chemistry" in Appleton, and the panel which we have now and which will discuss "Progress in Pulp Bleaching" will be moderated by the dean and vice-president of The Institute of Paper Chemistry. He graciously consented to take over this important function of our conference, and we welcome his very warmly.

Roy Whitney, as I mentioned, is dean and vice-president of the Institute. He graduated from the Massachusetts Institute of Technology where he got all his degrees. He is a member of the Technical Association of the Pulp and Paper Industry, the American Chemical Society, the American Institute of Chemical Engineers, the American Society for Engineering Education, and the American Institute of Chemists. His publications and presentations during TAPPI conventions and similar occasions are numerous. He is

active in several committees of TAPPI, and is presently chairman of the Fundamental Research Committee.

Dr. Whitney: Thank you very much, Dr. Kraft. It is a distinct pleasure and honor to be invited to moderate this panel discussion. A moderator, if we interpret the term strictly, is one who moderates, and the implication is that there will be something which needs moderating. I hope this is true. I hope that this panel discussion develops a sufficient level of interest, activity, and perhaps disagreement so that a modifying influence will be necessary.

We hope that this will be the kind of panel discussion which will stimulate your interest and your thoughts, and will be an opportunity for discussion not only among the panel members, but among all of you who are present. We should like it to be an opportunity to exchange views, to air differences of opinion, to assess our position in the general field of pulp bleaching and purification. We think that this panel discussion is not the place to present extensive new information of the kind you have been hearing about in the past two and a half days in the formal papers. Here we are not going to give lectures nor are we trying primarily to educate you. Rather we want to talk things over with you. We have a distinguished group of experts up here, and as I have said, I feel highly honored to be associated with them.

I should like to assure you that this is not a "canned" discussion. Deliberately, there has been a minimum of prior preparation. We have exchanged a couple of letters, and we got together for about an hour on Tuesday afternoon. I think that in our meeting Tuesday we succeeded in establishing at least two things. First of all, we agreed on the few simple "ground rules" that we'll try to follow in our discussion. Secondly, we became convinced that there is an ample opportunity for differences of opinion among our experts and that this should lead to a stimulating discussion.

Now the grounds rules are few and simple. Each panelist will be given an opportunity to make an initial statement. We have imposed rather strict time limits on this part of our program. We have tried to break up the bleaching field among the panelists insofar as their initial remarks are concerned, in order that we won't have all five of them talking about the same thing. However, we haven't deliberately tried to cover the whole field of pulp purification because we feel that this would be neither possible nor desirable in this setting. We shall finish this part of our program in an hour or less, and then we'll get to the real meat of the discussion. Here, we hope sincerely that you will enter in and that you will ask questions, comment, and offer opinions. We want you to assess our panelists' comments for yourselves. If you disagree with them, please say so. If you have comments to add, please do so. We shall judge the success of this session largely by the extent to which it becomes one of broad participation by you in the audience as well as by our panelists.

As you know, our theme is "Progress in Pulp Bleaching." This seems to suggest that there has been progress in pulp bleaching in recent years, and I for one am willing to accept this as a starting premise. The excellent papers presented at this conference provide convincing evidence that it is true. However, I, for one, am not convinced that progress in plup purification is at an adequate rate, or that it is aimed in the right direction. I wonder if much of our seeming progress is superficial. I wonder if it's aimed at doing the same old thing in slightly different ways, or perhaps aimed at relatively minor improvements in technique and efficiency. While we may have learned a great deal about how to bleach specific pulps for specific purposes under given arbitrary conditions, I wonder if our understanding of what happens and why it happens is developing adequately. In no sense do I wish to depreciate the excellent research which has been going forward in many laboratories both in this country and abroad, but I wonder if those people who are engaged in this research would not agree that we may be paying too little attention to the fundamentals. Are we learning enough about the basic requirements to be met in altering the optical properties of pulps, the possible reactions which may be involved, the mechanisms and the kinetics of these reactions, and the physical conditions which must be met?

In my opinion, progress in the broad area of pulp and paper technology has never been more rapid than in the past five to ten years. For example, ten years ago, we had only the most rudimentary knowledge of drainage and sheet formation on the wet end of a paper machine. As it developed, much of what we believed then was incorrect. Today, while we still have much to learn, we have made great progress toward an adquate understanding. As a result, we see serious limitations in both fourdrinier and cylinder paper machines, and much thought is being given to new types of forming devices which some day may replace these conventional instruments of sheet formation.

It wasn't many years ago that we talked about only three chemical pulps; soda, kraft, and sulfite. Each was a distinct process, and each was conducted in a narrow pH range according to specific conditions. Today we dream about a whole spectrum of pulping conditions in order to produce tailor-made pulps for specific purposes, and this dream is becoming a reality in quite a few places around the world. Continuous pulping is growing in popularity and several laboratories have demonstrated that cooking times can be shortened to a very few minutes.

Is the bleaching field keeping pace with these developments? Can we afford the massive equipment, the long retention times, the cost of chemicals? Are there audacious new approaches which might lead to entirely new and novel concepts of pulp purification? These are the questions which I'm going to ask our panelists to discuss and on which I'm going to ask your comments.

Our first speaker is Dr. J. A. Van den Akker. Dr. Van den Akker is a senior research associate of The Institute of Paper Chmeistry where he is head of the Department of Physics and Mathematics. He will discuss the physical and optical properties of pulps.

Dr. Van den Akker: Progress in pulping, bleaching, and reversion studies depends strongly on the accuracy and day-to-day precision of reflection meters and spectrophotometers. One should have a reliability in the measurement of reflectance of, say, 0.1%. Now, by way of illustration of this, I would like to cite the work of John Tongren. He, in 1937–38, and McIntyre the next year, 1938–39, did superb jobs on the reversion of bleached pulps; I don't think this work could have been done with such high quality unless the precision of the work—and I mean the day-to-day, week-to-week precision, not short-term reproducibility—was of the order of 0.1%. In our bleaching studies, however, if we achieve this level of precision, the precision is swamped by uncontrolled variables in a way that is hidden from us. In scientific and technical work, one must separate the variables. I don't think that we are separating the variables in a satisfactory way. For example, almost all of our efforts are based on reflectivity, R_∞, and this depends among other things on the degree of bonding between the fibers. When we make changes in the cooking or bleaching and proceed to make sheets for optical testing, we simply don't know how much we have changed the extensiveness and level of bonding between the fibers. This is a significant factor which is, so far as most of us are concerned, quite completely hidden.

Several times, we've seen the formulas from the Kubelka-Munk theory, giving R_∞ as a function of k/s and k/s as a function of R_∞. We have also discussed means for determining the separate coefficients—the specific absorption coefficient, k, and the specific scattering coefficient, s. In our various laboratory and technical studies we should concern ourselves more with k and s, particularly as they vary with wavelength. Practically everything we've heard at this meeting on optical properties has been in terms of bright-

ness. We haven't known how much s has changed as a result of changes in bonding between the fibers and, accordingly, how much k has been spuriously affected. Well, gentlemen, this is all wrong! By way of stirring up a tempest in our carbohydrate pot, I'd like to suggest that we should forget brightness for the purposes of study (and perhaps ultimately for the purposes of specification, although we shall always find it convenient to use brightness as a single number measure of the colorimetric potential of a pulp). We should be dealing with k and s, not just because these quantities sound more "scientific," but becuase when we work with k and s, we're dealing with the very things we should be concerned about and we're not getting our variables all mixed up. Think of the advantages of working with these quantities: You can see how you're progressing in terms of the fundamental optical properties; you can determine k as a function of wavelength, and make analytical studies, as we indicated in the first paper; and I think practical people will have more respect for your achievements! Several people have had occasion to talk about the difficulty of going from an absolute reflectivity of 0.90 to 0.96, to something higher. The slope of the relationship between R_∞ and k/s approaches *infinity* as R_∞ approaches 1.0; k/s approaches zero—and, of course, k must approach extremely low levels corresponding to values of R_∞ that are significantly less than 1.0. This doesn't show up at all well when you're talking about brightness or any other reflectivity. If you just talk about numbers like, 0.90, 0.95, 0.98, nobody has any real respect for the changes that have taken place! Now, 0.90 is a pretty respectable absolute reflectivity. If we want to go from there to 0.99, which is only "9 points" on the ordinary scale, we have to decrease the absorption coefficient by a factor of 111. This properly reveals the change.

We have the means today to make accurate determinations of k and s. The combination of proper measurement of total transmission, T, and R_∞ provides one with the means for measuring k and s quite reliably.

Some illustrative calculations show the advantage of this process. Let us consider a case where T is only 0.10 or 0.15, corresponding to a fairly heavy sheet. Using a good spectrophotometer or reflection meter, the error in T will be about 0.01. Corresponding to this (for any ordinary value of R_∞—like 0.80), the error in k will be about 1%, which is quite good; to give one a feeling for the measuring of this order of error in k, a 1% change in k produces a change in reflectivity (e. g., brightness) of only one part in 800 at 80% brightness. The details for determining the k and s values through measurement of total transmission and R_∞ are given in the first paper.

I should like to direct a few remarks to the often-raised question, "Is there a theoretical limit, less than 100%, to the brightness that may be attained through extremes in bleaching?" First, brightness is measured on the MgO scale with the (45°, 0°) geometry. *For this geometry* we do not know exactly how the reflectance of MgO compares with that of the hypothetical ideal diffuser; to be more accurate, we do not know this comparison for the particular MgO scale on which standard brightness is based. (Over a period of years the brightness scale has been standardized through determination of the absolute reflectance of MgO, *using the integrating sphere geometry;* for this geometry, the scale has been fixed at an exact value just under 0.98.) According to the work of McNicholas at the Bureau of Standards, many years ago, the reflectance of MgO for the (45°,0°) geometry is very close to that of the ideal diffuser. We also know that the reflectivity of a handsheet determined with the integrating sphere geometry is slightly higher (same spectral conditions) than brightness, when MgO is used as standard; but the absolute reflectivity of the handsheet is rather close to standard brightness. Although the small difference may be technically or commercially disturbing, we may assume for the purposes of this discussion that brightness is essentially equivalent to R_∞. We may then say that the theoretical limit to brightness is 1.0 (or 100%).

But we must recall the great slope in the R_∞ versus k/s relationships at high values of R_∞ (and that it approaches infinity as R_∞ approaches 1.0). In special laboratory studies of the sort conducted by Howard Rapson, designed to achieve very pure pulps of high brightness, the slightest contamination of the water or of the air in the laboratory would hold the reflectivity down (i.e., prevent k from approaching zero). In addition to traces of sorbed soluble compounds, tiny black or colored particles in the fibers which would cause no significant effect at $R_\infty = 0.90$ may become extremely important at $R_\infty = 0.99$ (k you will recall, must be 111 times smaller), and positively prevent the attainment of $R_\infty = 0.999$. If then, one wishes experimentally to explore this interesting academic matter (which may have important implications for commercial production at ordinary, high levels of brightness), he should be extremely careful in the selection of all materials, including the wood. Perhaps the tree itself should be selected, and the wood taken from a portion of the tree where, in principle, and by inspection, the contamination is minimum; the wood should be chipped in a special chipper; all the water and chemicals employed in the various pulping, washing and bleaching operations should be as pure as possible; finally, the air of the laboratory should be filtered with a so-called "absolute filter!"

Dr. Whitney: I wonder if there is a fundamental difference between pulping and bleaching? They're both concerned largely with lignin removal. I wonder why we have the bleaching sequences we do. I wonder why we use the number of stages we do. Dr. Hans Giertz is going to talk about some of these things. I don't think that we need to introduce Hans to you, since has has given a paper earlier. He is now a professor at the Technical University in Trondheim, Norway, and we're delighted to have him with us.

Dr. H. W. Giertz: Our chairman has already given the questions. Why are we bleaching? Why do we have to bleach in so many stages? Why isn't it possible to get the bright pulp in just one stage? Let us face the very important fact of, for instance, chlorination. As you know, the chlorination reaction stops after a certain time and the reaction doesn't proceed even if there is an excess of chlorine available. After an alkaline extraction, however, chlorine reacts rapidly again, but only to a certain new level, and never to a completely lignin-free pulp. Why is it like this? This is of course a very important fact for us in technical work. No one can give the answer today, but perhaps I could just talk a little about my ideas concerning it.

Yesterday it was mentioned that we might have some lignin in the fiber wall and not only in the fiber surface. I will follow that line of thinking. Between the celluloses microfibrils in the wall (S_1 and S_2) there are capillaries filled with hemicellulose and lignin. Now chlorine enters the capillaries from the end and reacts rapidly with some lignin.

What does this reaction involve? We saw from the pictures earlier at this symposium that the hydrophobic lignin is rendered hydrophilic by chlorination. This means that it absorbs water: it swells. So the whole interfibrillar material, both hemicellulose and lignin, will now swell, and it might be that this swollen lignin may plug the whole capillary so further chlorine will not enter and react with the part farther in the capillary. It might also be that this chloro-lignin forms some kind of a semipermeable membrane where the chlorine can't go through. We know today that membranes having acid or basic groups are a hindrance for ions. The chloro-lignin has an oxidation potential and it might act in somewhat the same way. This kind of topochemical reaction is typical for all acid types of bleaching. It is exactly the same for chlorine dioxide, and therefore, we have to repeat the chlorine dioxide treatments. But as hypochlorite is alkaline, there will be a continuous dissolution of the reaction product and the reagents can proceed. Another point of

interest might be; why do we have to use so much chlorine? The chlorination is nothing but delignification. And why couldn't we make this delignification more complete in the digester? That would of course be much cheaper. The ideal thing would be to take out all the lignin in the digester and then to bleach in just one single stage with small amounts of hypo or chloride dioxide. I think we know a little more on that point. Some lignin is obviously very difficult to dissolve in the cooking process. We have no reason to expect that some part of the lignin in the native form is more difficult to dissolve than the main part. Being a scholar to Häggland, I think the whole story is that we are rendering the lignin insoluble in the cooking by condensation. In sulfite cooking, this definitely takes place. It's a kind of bakelite formation, and it takes place to quite an extent in pure soda cooks. If there is sulfide present at the same time, this in some way covers the reactive groups, forming, it is suggested, a lignin sulfide and then the lignin can no longer react in the condensation in our sulfate cooking and the condensed lignin will never dissolve in the digester and we have to break it down in our bleaching operations.

In sulfite cooking, I think we know more about the condensation reaction. It is catalyzed by hydrogen ions and becomes of importance at temperatures above about 100°C. It takes place over the same reactive groups which can be sulfonated. Therefore, sulfonation is a way of avoiding condensation and, beside rendering the lignin water soluble, this is a very important result of sulfonation which should not be overlooked.

If we study these problems more carefully, there might be something to win and perhaps we can reduce the number of bleaching stages.

Dr. Whitney: So you see all of the difficulties in bleaching don't come from the bleaching sequence but some of them result from pulping.

We're going on now to Howard Rapson, of the University of Toronto. Howard certainly doesn't need any introduction to this audience. He's been working very actively in the pulp purification field and is one of the real experts on this continent in pulp purification.

Dr. W. H. Rapson: I agree with Van very much that we should be able to discuss absorption coefficients and scattering coefficients and our work would be greatly improved if we could. But as a matter of practicality, in preparation for Fig. 1 on my paper yesterday, I had to have 90 different brightness measurements made one day and 90 aged brightness measurements made the next day. Can you do this and determine k and s separately, at 90 measurements per man day?

Dr. Van den Akker: Seriously, the complete job, including the weighing of specimens and reading the charts, would require about 4 man days.

Dr. Rapson: Well, that would be very good. We would be very glad to spend many days to obtain proper absorption coefficients, but we don't possess an integrating cavity of the type that will give the proper measurement for transmission. There are a lot of difficulties, but I agree with Van that this is what we should do.

When we bleach to the very high brightnesses Van was talking about, we are approaching a limit asymptotically. There are several effects of this approaching a limit asymptotically.

First of all, there isn't much higher brightness to be achieved. There may be argument about exactly what the high numbers means, but there isn't very much further to go. Secondly, the chemical cost increases sharply as we get up near the asymptote of the curve. Thirdly, and this is most important of all, mal distribution of chemical can only lower the average, because we cannot make some of the fibers brighter to make up for the ones that don't reach maximum brightness. There isn't any higher brightness level to be reached. Therefore, if maximum brightness is not achieved by some individual fibers or by any portions of the pulp, this cannot be offset by some other part being bleached to higher brightness. This can be done at lower brightnesses. At 70, 60, 40, or any level, you can bleach some fibers to a greater extent and some less and get a nice average anywhere you want. You can't do that at the maximum level. This concept applies to every bleaching stage and especially in chlorination. If pulp is not completely and properly chlorinated, you all know that you cannot reach the same level of brightness no matter what stages or bleaching agents may be used. Adequate chlorination is the *sine qua non* of reaching maximum possible brightness. However, again looking at the individual fibers within the pulp mass, underchlorinated fibers can never be brought up to the peak brightness later in the bleaching. In any chlorination stage, a lot of fibers are overchlorinated and a lot are underchlorinated. Yet if we're going to reach these top levels of brightness, there must be uniformity of chlorination so that no fiber is underchlorinated. And as you know, of course, the overchlorinated ones lose strength. These are some of the many reasons for multistage bleaching. Therefore, I do not really think that progress toward still higher brightness is going to rest very much on new bleaching chemicals. There is very little higher brightness to be gained. I believe that with existing chemicals, much improvement is to be gained along other lines.

First and most important is improvement in equipment. Secondly, we must get these better pulps at lower cost. We must lower the capital cost of bleaching equipment. We must lower the chemical cost of the chemicals required in bleaching. We must lower the operating cost, reduce manpower, reduce all the auxillary services that cost a lot of money, and we have to improve the control of variables. All these things are necessary if we're going to reach these high levels with minimum of cost.

Now, in my opinion, the most important factor in all bleaching is mixing of chemicals with pulp. There's no use trying to develop better bleaching agents unless we get the most out of the ones we have; this can only be done if every fiber gets its quota of bleaching agent at the right temperature for the right length of time.

Mixing is the greatest difficulty in chlorination. People get what they think is good mixing and they're happy with it, but better results can be obtained with even better mixing. No one type of mixer is good enough, in my opinion. Each type of mixer has something to add to the work done by others, so the best thing of course is to have more than one mixer. For example, an aspirator should be used to suck the chlorine in with water, to break it up into fine bubbles, then put it thorugh one mixer, say a Hooker stationary mixer, and then put it through a double shaft mixer, and then put it into a tower that keeps the pulp stirred up for a few minutes and then you get adequate chlorination. Caustic extraction is not as critical as far as mixing is concerned, but all those in the dissolving pulp business know how important it is to mix the caustic solution uniformly with the pulp. Chlorine dioxide is less critical than the chlorination but good mixing is still very important.

Chemicals must be brought to a lower cost. As an example, chlorine dioxide, when first made in Natchez in 1950, because of the crude method of manufacture and the expensive chemicals, cost 35¢ a lb. Now 20¢ is very common. Average figures for two mills have been given me at this meeting. One was 19 $^1/_2$ and the other 20¢ per lb of ClO_2. This year some mills are going to make ClO_2 for 15¢ a lb. and we have methods under development that have a target of about 12¢ a lb. in the pulp mills. This is the best way to lower the cost of bleaching to current or any higher brightness levels. This is the direction in which we're going to go.

New as far as the newer chemicals are concerned, I foresee, if it gets cheap enough, that sodium borohydride will have a broad application as I mentioned yesterday, and perhaps paracetic acid might have some use. But I don't think this

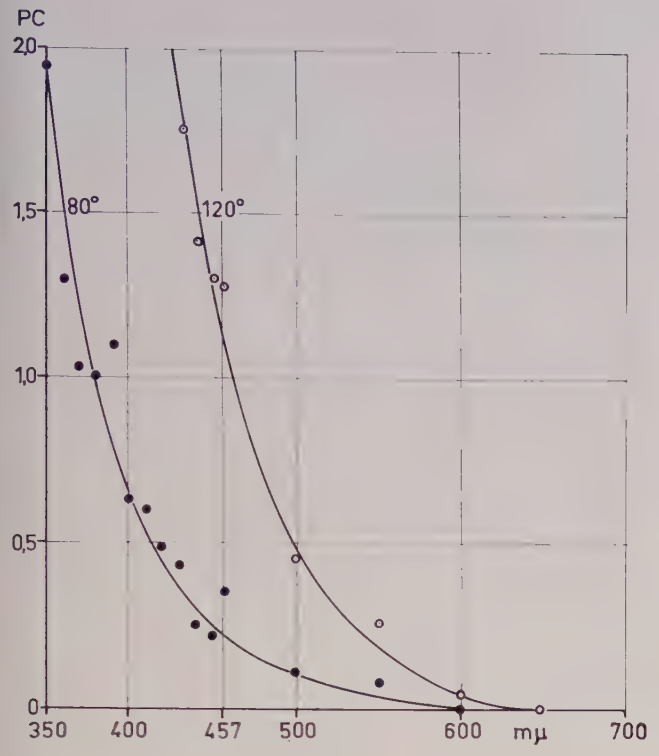

Fig. 1

is the direction in which we need to go. It's these other things I've mentioned.

Dr. Whitney: We're going on now to our next speaker, who is Dr. Nils Hartler. He has also spoken earlier at this conference, so you know something of his background. You know that he's from the Swedish Central Labs in Stockholm.

Now if we're going to have these very high brightness pulps, it is necessary, of course, that the brightness level be stable. We have heard something about color reversion at the conference in the last couple of days, and Nils is going to talk still further about color stability and brightness reversion.

Dr. N. Hartler: Color reversion was dealt with very thoroughly and in an excellent way in the first session during this meeting and we agreed at that time that we didn't like it. However, I am going to take it up again from a few points of view that I feel are of greatest importance.

The first one is *the method* that we are using to determine the color reversion. The conditions were developed mainly with the aim of getting a lowering in the brightness of a magnitude large enough to measure with a good accuracy. The most commonly used conditions, i.e., 120°C. for 16 hr., are far more severe than those prevailing during natural aging. Figure 1 shows the influence of temperature upon the aging. To the left we have the reflectivity versus wavelengths and there are three curves, one for the pulp before aging, one after aging at 80°C. for 16 hr., and one after aging at 120°C. for 16 hr. The results have been recalculated into pc-numbers as shown to the right also as a function of wavelengths, and we see that the sample aged at 120°C. has a pc-number when measured at the ordinary wavelength of 457 mμ, which can also be obtained for the 80°C. sample by using approximately 375 mμ. Mr. Stenius at our laboratory is working on this and related problems right now. Another point of interest as far as the conditions during the aging are concerned is the relative humidity. Usually the test is performed in an oven at a low relative humidity whereas during natural aging it is not so. The influence of the relative humidity during the pc-number the ratio between the absorption coefficient and the scattering coefficient is used, whereas from the yellowing point of view it is only the former that is of interest. We, therefore, ought to separately determine the absorption coefficient and base our calculations on k rather than k/s.

In connection with evaluation of bleached pulps we usually base our comparison on the brightness after bleaching. In addition the color reversion usually is determined and this information is used for comparison purposes separately from the brightness data. I think it would be better if brightness and reversion data would be used together in the way that the pulps would be compared on the bases of aged brightness rather than final bleach brightness. This may be illustrated by an example. In one case the final bleach brightness is 90% G.E. and the aged brightness 88% G.E. whereas with another bleaching method the final bleach brightness of 92% G.E. is reached with an aged brightness of 88% G.E. Oridnarily the later pulp would be judged as better from brightness point of view, however, having a more pronounced color reversion than the former pulp. Judged on the basis of aged brightness these two pulps would, however, be considered as equal. A few extra points in final bleach brightness are very costly to achieve and the presented example shows that they may not under any circumstances be so particularly desirable. When using the suggested method it is of greatest importance to have a proper method for determination of color reversion which gives not only qualitatively but also quantitatively information about the extent of the color reversion.

We have studied the influence of different bleaching agents as well as removal of resins upon the color reversion as measured by aging at 120°C. for 16 hr. Prebleached (chlorination and alkali extraction) sulfite birch pulp was used and as a final stage of bleaching, hypochlorite, chlorine dioxide, chlorine dioxide followed by an alkaline extraction with the addition of a small amount of hypochlorite as well as hydrogen peroxide. In all cases the color reversion was determined on bleached pulp samples as well as on bleached

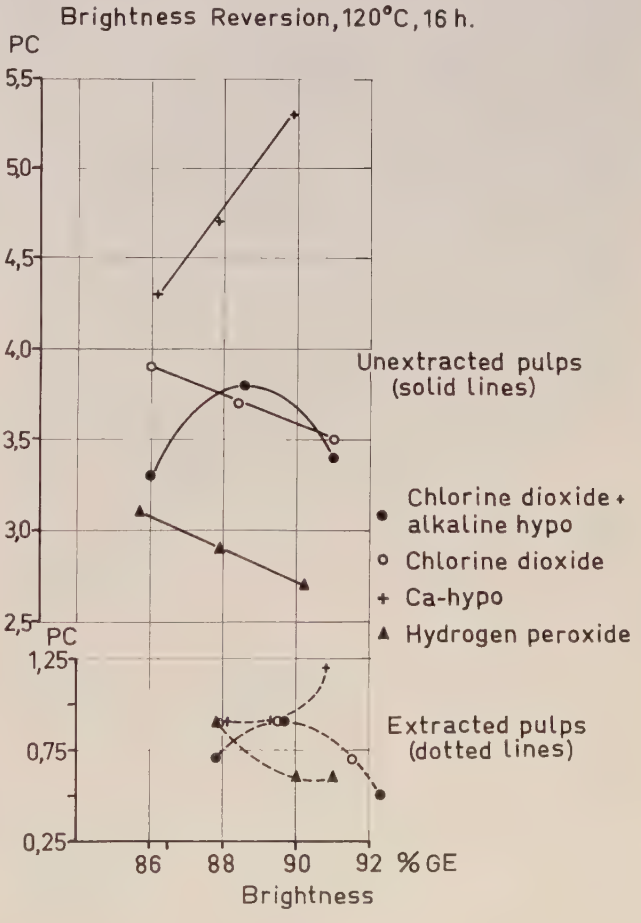

Fig. 2

pulp samples that had been extracted with ethnaol benzene (50% by volume). The result is presented in Fig. 2 where pc-numbers are plotted against final bleach brightness. As is seen from the upper part of the curve large differences were observed as a result of different bleaching agents. However, as a result of solvent extraction the pc-numbers are very much lowered and regardless of bleaching agent approximately the same pc-number is observed. This indicates that the differences as observed before solvent extraction are due to different response of the extractives to the bleaching agents and not so much due to different response of the carbohydrate portion. We are not in a position at the present time to make a more general statement in this respect. However, it has initiated a study of the influence of various bleaching agents on the different components of the extractives in order to find out whether there are some specific components of the extractives that are mainly responsible for the observed phenomena.

As was shown in Fig. 2 the color reversion is much less for a pulp bleached with hydrogen peroxide than for a pulp bleached with hypochlorite (pH 9). Throughout the investigation we have so far found this to be the case. We have used various proportions of hypochlorite and hydrogen peroixde in the final stage bleaching with hypochlorite always preceding hydrogen peroxide. The conditions were adjusted so that in all cases the same final brightness of 90% G.E. was obtained. The color reversion of the thus-obtained bleached pulps was determined and the result is seen in Fig. 3

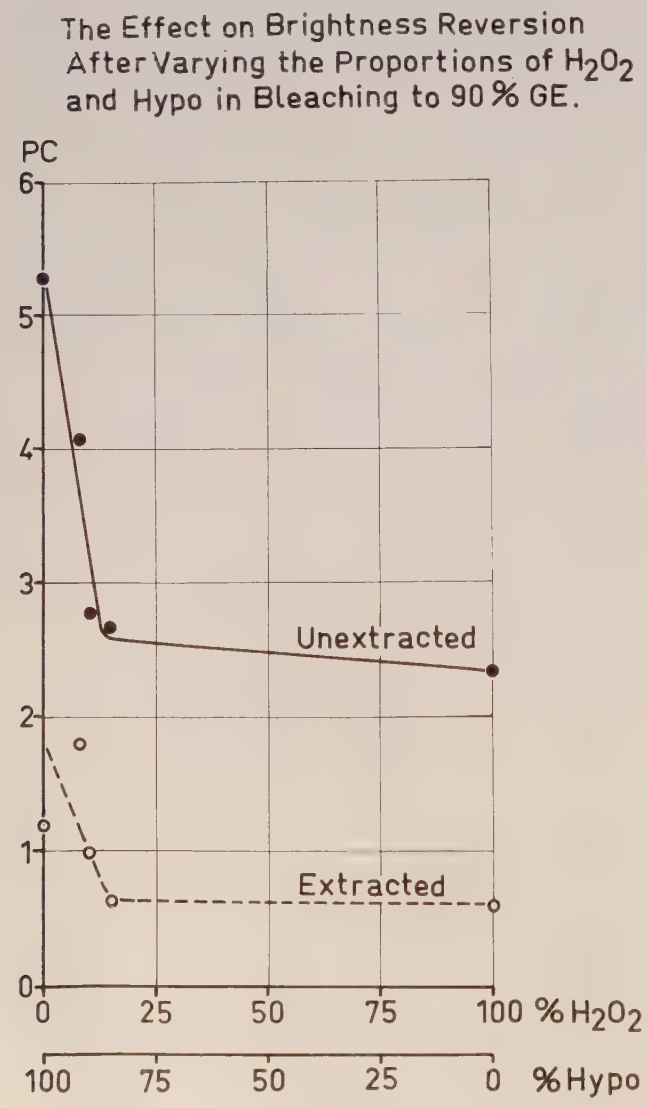

Fig. 3

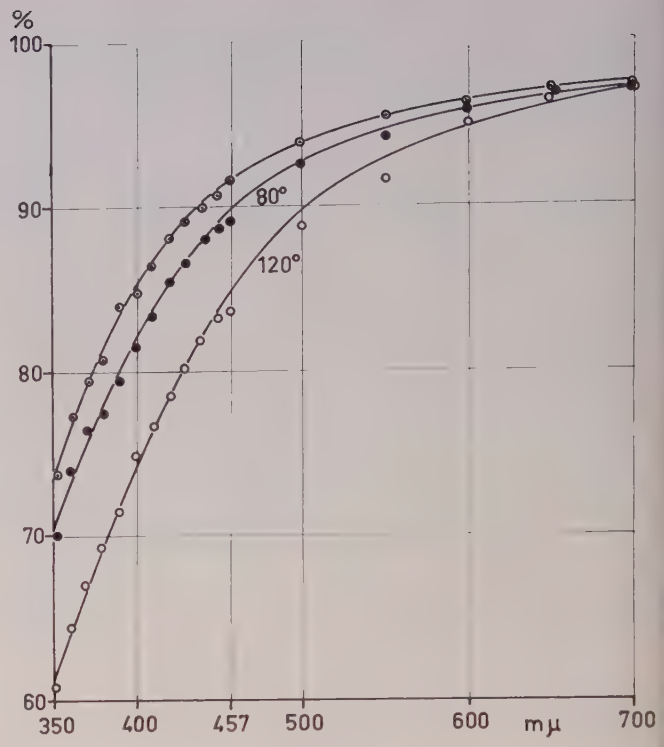

Fig. 4

with pc-numbers as a function of per cent hydrogen peroxide used in the final stage bleaching. This shows that the low pc-numbers that were obtained using entirely hydrogen peroxide also can be obtained using only a fairly small amount of hydrogen peroxide as the last stage of the final stage bleaching. This was studied for a birch paper pulp and if it is true for all types of pulps it means that a fairly small charge of the expensive hydrogen peroxide can be applied still having nearly the full effect in sofar as color stability is concerned.

Dr. Whitney: We come now to our last speaker. You know Jack Stevens, I'm sure, and as you might expect he is going to discuss pulp purification for nonpaper uses. This tremendous field is certainly deserving of our attention. Jack is with the Canadian International Paper Co., and he is manager of their dissolving pulp mills in Canada. He received his education at the University of Toronto, from which he holds Bachelor of Arts and Science and Master of Arts and Science degrees.

Mr. Stevens: The part of the discussion that I would like to dwell upon deals with pulp for nonpaper uses. The trend of discussion throughout these last few days has emphasized pulp brightness. In every session we seemed to get into detailed discussion on the relative brightness and color of the actual pulp sheet or paper sheet that is being made. I would like to bring your attention back to the fact that there is a large section of the pulp and paper industry where the actual brightness of the pulp and paper sheet is of relatively second importance, and that there are other more important things that we are trying to do to adapt these pulps to nonpaper uses. For the benefit of those in the audience who may be relatively unfamiliar with pulps other than for paper and board, I would like to briefly introduce my subject of nonpaper uses by explaining some of these uses and, the volume or tonnage required.

We find that production of pulps for this section of the industry has more than doubled in the last ten years and that on this continent alone it amounts to some 2 to $2^1/_2$ million tons and overseas in such places as Europe, Scandinavia, South Africa, and so on there is approximately the same tonnage. We are dealing in millions of tons of pulp for ther nonpaper uses, and therefore, this is an important section of the usage of cellulose. When we look at these

nonpaper pulp uses in detail, we find that we're no longer just trying to bleach the fiber. We're trying now to make a chemically pure raw material.

Cellulose forms the raw material for such processes as the viscose industries with the ultimate aim of making and products such as rayon, rayon filament yarns, tire cords, staple fiber, cellophane, CMC, and cellulose sponges. Another section of the industry requires purified cellulose for the acetylation field with the end products clear plastics, films for photographic purposes, x-ray films, acetate rayon, and tow for cigarette filters. Other sections are nitration; cellulose derivatives such as hydroxyethyl cellulose by special process; fillers for plastics, in combination with urea formaldehyde and melamine resins; and other miscellaneous usages such as welding rod coating, filter aids, flocculating agents.

For raw materials, of course, the same woods are used as as for the paper industry. You find the softwoods, the spruces, pines, firs, hemlocks, etc., being used. Hardwoods are playing an ever increasing part. You find birch, poplars, gums, beech, eucalyptus, and so on being used today. And thirdly, we have a large amount of cellulose for nonpaper use supplied through cotton linters.

Cooking processes originally were based on the sulfite industry; all four bases are being widely used today. More recently, the kraft industry came into the dissolving pulp and nonpaper uses through the prehydrolyzed process with sodium being used as the base.

In bleaching sulfite pulp, basic two and three-stage processes have expanded and developed into multiple-stage systems, based on combinations of chlorination, hot alkali extraction, cold alkali extraction, hypochlorite bleaching, and chlorine dioxide bleaching. When kraft pulps entered the nonpaper field, additional stages were necessary, and bleaching sequences of five to seven stages and even more are used.

Because of the complexity of bleaching processes, it is necessary to give more attention to the fine details of each stage. Things such as pH, temperature, consistency, time, residual, purity of wash water, are very important to every individual stage. It is necessary to maintain extreme uniformity in the pulp being made because it is going on into other delicate and intricate processes where the least variation can throw the whole plant out of gear and actually shut it down. Alpha-cellulose is an important characteristic and has to be controlled within a very narrow range. Viscosity or D.P. of the cellulose has to be controlled to any level required by the client and within very narrow ranges. Deresination is important, very much more important than in the pulp and paper field. In fact, we are always striving to more or less make completely deresinated pulps. Removal of mineral impurities is very important as they can catalyze some of these processes that the pulps are going into. The hemicelluloses, especially the gamma type, have to be reduced to minimum levels. Processing stages are regulated to impart properties to the fiber that will give desired sheet characteristics. Cleanliness and brightness is of importance in that the dirt that you cannot see or that is relatively small is of major importance, and can upset the filtration stages of the following processes. During recent years, another factor has been added to our many problems and that is radioactivity. It is necessary to watch and control the fallout content of the plant atmosphere and of process water because some pulps are going into very sensitive x-ray films, photographic films, and papers where such contamination would cause exposure.

It is essential to produce pulps that will mechanically work in the converter's processes. By this I mean you have sheet properties to attain that will make these sheets steep or slurry properly, and lead to good filtering characteristics of the dissolved or treated cellulose solution that goes on into the yarns and films.

The emphasis is thrown on the pulp manufacturer to maintain uniformity of what we call reactivity. In other words, the extent or the rate at which the pulp will process in the converter's plant has to be maintained at a high and uniform level. Production of pulps that will give yarns or films of high and versatile strength is important. Other factors such as bulk density of sheet, porosity, and absorption are important to many of the converting processes.

These are some of our problems or some of the things that we are trying to control in our bleaching and refining stages when making pulps for nonpaper uses.

The section of the industry producing pulp for nonpaper purposes is in a position more or less relative to the ham in the sandwich. On one side, we have rising costs due to rising labor costs, rising material costs, equipment costs. On the other hand, we are striving to give higher purity of cellulose and at less selling price. How are we going to do this? How are we going to eliminate some of the roadblocks? We have to investigate our refining stages, our bleaching sequences in order to carry out the purification with less loss of good cellulose. If you have knowledge of what goes on in a dissolving pulp mill, you can realize that from the unbleached pulp to the finished pulp you can have a shrinkage loss of anywhere from 20 to 30% on some of the more purified grades. We, therefore, need maybe new purifying processes, maybe new bleaching agents to accomplish these things with less loss of good cellulose. Have we studied enough the effect that might be obtained from other chemical additives in our bleaching stages? Or additives that can be added to the pulp produced for specific characteristics? Going further back before the bleaching of the pulp, I think we have to look to the cooking processes, and also to the wood quality, in relationship to bleaching. We recover only a portion of the good cellulose that is present in the wood. We throw away the hemicelluloses. Are these of importance to us? Other factors that we have to consider are the recovery of a greater precentage of the inherent strength of the cellulose chain and the cellulose fiber. We are not, in my opinion, doing a very good job in this. You find that the very best of tire cord pulps today maybe approach a strength factor of 5 g. per denier. How are we going to compete with the improved nylons that have 6, 7, and 8 g. per denier? Yet we find from research work that has been done in the past that the fundamental inherent strength of the cellulose fiber chain may be as high as 10 or 11, maybe 12 g. per denier. On this basis, you can see that we're only recovering a percentage of what maybe is there.

In the last few days, we have heard discussions on many types of bleaching stages. Dr. Rapson mentioned that he's finally been able to put two bleaching chemicals into the same liquor. Is it possible that we can go further than this and put all the bleaching chemicals into the same liquor and all into the same stage and carry out a very streamlined process?

Another roadblock to our segment of the industry is that we lack a coordinated effort for development and sharing of fundamental knowledge to strengthen the position of cellulose pulps for nonpaper uses in the chemical fibers field. I believe that we are going to have to do something about this if we're going to hold the line against further inroads of other sythetic fibers and films.

Dr. Whitney: Thank you particularly for your latter remarks, which seem to me to be very pertinent to our present discussion.

We have now heard from each of our panel members with their various comments and opinions. We have certainly heard some difference of opinion. We come now to our period of open discussion, which should be most interesting. I have a number of written questions and perhaps it would be as well to start with these.

The first question is from Dr. Luthgens and is aimed at Dr. Rapson. "Howard, you spoke about the distribution and uniformity of brightness of high level bleached pulps.

Was the brightness of individual fibers ever measured?" Dr. Luthgens, would you care to elaborate on this question?

W. W. Luthgens (Nalco Chemical Co.): I think, as was pointed out during this meeting, that the nonuniformity in the distribution of the brightness of any pulp is also true at high brightness levels. Now it would be wonderful to know the brightness of an individual fiber, but I don't think this was ever done. I think there is a big difference in the distribution of a brightness in a pulp.

Dr. Rapson: This question should be addressed to Van who is, in my opinion, the world's expert on this type of thing. I know nothing about the brightness of individual fibers. We have classified pulps by fiber length of course, and like you, got wide differences in brightness among the various fractions. Van should answer this.

Dr. Van den Akker: I'll not quibble about what we mean by the brightness of a single fiber. One would have to make an experimental definition of this. We have made some attempts to measure the light scattered by single fibers in some work that has yet to be published—in an entirely different connection. What would have to be done, in my opinion, is to measure the light scattering by a single fiber and also the light absorption. We know from our experiences of the last three or four years that measuring light scattered from a single fiber is a difficult job requiring the use of photomultiplier tube and a very careful experimental setup; and the results are highly variable, as you might expect for something as irregular as an individual fiber. However, the measurement of the spectral absorption coefficient of a fiber would be very difficult indeed in view of the exponential law of absorption. As you know, the individual fiber is only a few microns thick, and it would be very, very difficult to measure the light absorption in single fibers with any accuracy at all. I don't think it could be done.

Dr. Rapson: Qualitatively, couldn't you look at a lot of fibers under the microscope and get a mental impression of variations in brightness among the fibers?

Dr. Van den Akker: I don't think so.

Dr. Rapson: Well, then, let's put it another way. Suppose we were able to plot a distribution curve of the number of fibers having a certain reflectance against that reflectance. Some would be higher and some lower than the average. My thesis is that at the highest brightness level none would be over, some would be under, but there is a cut-off in the distribution curve at some high level. I don't know whether this idea is sound or not.

Dr. Van den Akker: I think your speculation on the point is very valuable.

Dr. Whitney: There's a question here from Dr. Sarkanen that I think gets to the heart of the matter. Also addressed to Dr. Rapson. "How can you justify the statement that probably nothing is going to be gained from new bleaching chemicals as long as our knowledge of the chemistry of bleaching is practically nonexistent?" Dr. Sarkanen, would you care to amplify this?

Dr. Sarkanen (College of Forestry, State Univ. of N. Y.): My criticism against the present line of research in the bleaching field is this. I think that we are moving on a very narrow sector. We are doing plenty of repetitious work. We don't modify our approach too much, we modify the pH, we employ different bleaching stages and so on, but we don't try to widen the sector of research. Moreover, when we describe the results of our studies, we are used to employing certain words and characterizations which have little meaning. As Dr. Van den Akker pointed out, the brightness has a certain amount of vagueness. I would like to bring up some other words. One is color bodies. I have tried to introduce the word "chromophore" which corresponds better with the species with which you are dealing. Another is condensation which Dr. Giertz stated is a rather vague concept. I think as long as we are operating in an atmosphere of vagueness we are not justified to make any statements about the future. I was just wondering if Dr. Rapson had been asked the same question back in the twenties whether the answer had been similar. Of course, after it was discovered, chlorine dioxide is an excellent bleaching agent. I think that it is quite possible that in the future we will find a bleaching agent which can do a magnificent job in one stage and I think this possibility is certainly within practical possibilities.

Dr. Rapson: Thank you, Dr. Sarkanen. I'm glad you addressed this question to me because I wouldn't want it thought that I was not appreciative of the importance of fundamental work in fields like this. I must say though that I had not given much thought to it in the 1920's since I began elementary school about 1920! But nevertheless, I appreciate the value of fundamental work very much. However, we have to look at the other side of the picture. Had we waited for the fundamental progress to be made first and then gone after what could be derived from it, our technical progress in pulp bleaching would have been held up tremendously. It is the history of a great deal of technology, and especially the pulp and paper industry, that progress has been made empirically and later, the theory has been developed. However, periodically we come to a technological plateau, and progress in theory is needed to establish for us another goal and provide the tools for moving forward to another plateau. I do not believe that we had reached a plateau in bleaching ten years ago. I believe the progress we have made in the last ten years, empirically, has been tremendous. I think it is possible we may have reached a plateau now and need a great deal more effort in fundamental work. I believe that fundamental work should be along simultaneously with empirical investigation, and that in this way this country and many other countries have made tremendous progress. This is not to belittle fundamental work. It would ill behove a professor to take such a stand! But we have to be practical and that's why I made the statement that I thought we needed engineering work in bleaching now while the fundamental work catches up. I've tried every bleaching agent I can think of. I'd be glad if anybody would suggest some I haven't thought of, and I'll carry out some empirical investigations on them while pursuing fundamental work at the same time.

Dr. Whitney: We have a philosophical point here that I hate to leave if someone else wants to comment.

Dr. Herbst (Industrial Cellulose Research): I strongly disagree with anyone who implies that we have exhausted all the possibilities in a semiempirical way in improving our bleaching processes. In the past three days, the only mention of catalysis with bleaching processes was in papers on peroxide, in which any kind of catalysis is the noxious kind. I am of the opinion that there is a large field for future investigations in work on the catalysis of our bleaching agents.

Dr. Whitney: That's an interesting comment and offers one approach that certainly merits investigation.

Dr. Tongren (Hammermill Paper Co.): We have talked about chemicals and new bleaching agents. What about the possibility of radioactive materials perhaps coupled with such things as high frequency? Is it possible that certain types of radioactivity will get at these materials that are so hard to reach?

Dr. Van den Akker: The only cellulosic material I have ever seen that was exposed to gamma rays for a long time got very yellow. Radiation of the gamma ray type or high-energy particles will cause failure of bonds. There is vastly more energy available than is required to break any chemical bond but I would hesitate to speculate on the possibilities.

Dr. Rapson: I'd like to say a word if you don't mind. We are not so empirical as it might seem. We are using perhaps the world's most intense source of gamma radiation for work on cellulose, particularly the formation of free radicals within the cellulose. We are using these free radicals as initiators for polymerization of such things as polystyrene on the cellulose backbone. We've already made a

cellulose where the polystyrene on a cellulose backbone has a rather high molecular weight. This is done under very simple conditions. We're also studying the effect of the gamma rays on the cellulose. The damage to the cellulose is a function of the dosage of radiation, and it takes substantial doses to damage the cellulose seriously. Papers have been published on this, but tremendously large dosages were used. Small dosages don't hurt the cellulose but they do form free radicals. We can use these for initiating many other types of reactions as well as the polymerization which I described. The properties of our grafted polystyrene on cellulose are changed. The material is not longer soluble in cupriethylenediamine nor any cellulose solvent. It is no longer soluble in any styrene solvent, and in fact, is therefore, very difficult to work with. Nevertheless, I agree with what Dr. Tongren has said, we should use any tools available for imaginative investigations into all sorts of fields and this is where the future lies. The present, for progress in bleaching, I still believe, lies in improved engineering.

Mr. Patterson (Columbia Cellulose): We have dabbled with gamma radiation as a means of cleaning up some of our seal boxes and bleaching liquors. It takes pretty massive doses but you can get rid of quite a useful amount of dissolved material in that way, thus economizing on your liquors. With regard to the use of other forms of energy, Georg Jayme in Darmstadt has published a couple of papers on the use of ultrasonics. I think he applied that in bleaching also. I think he's continuing with that work.

Dr. Whitney: Is there any further comment on the question of the relationship between empirical and fundamental work? We're getting away from this toward possible avenues of investigation.

I for one would say we should certainly not cease our efforts along empirical lines. Howard used the word "practical," which I don't like in this context because I think fundamental work is just as practical, and perhaps often more practical than the empirical. However, I also feel that we should step up very greatly our fundamental effort. I think that a proper balance has not been reached in this field and that we must learn more of a fundamental nature about this cellulose fiber and its associated materials which are of so much interest in pulp purification. As we do this, we will learn that some of our techniques can be improved and some of them are not adequate. I wonder if you've ever thought of research as an experiment in obsolescence. The more successful is the research, the more quickly the equipment that is now being used will be come obsolete. And this is a rather serious roadblock in some instances, because bleaching systems are not inexpensive. No company wishes to discard one when it's operating satisfactorily, even though there may be better ways of bleaching. Very often, a measure of a company's audacity and faith in research is determined through its willingness to face the obsolescence which research brings about.

Dr. Rhys (Chihuahua): I studied some of these questions, and maybe we are forgetting to take some of the important elements into consideration. In different kinds of wood, for example, you have completely different fiber size distributions. In eucalyptus wood, for example, the fiber size distribution is very small, whereas in ponderosa pine the fiber length may go to 7 mm. The two woods should be treated in completely different ways. Thus, when these pulps are beaten, either bleached or unbleached, one may be transferred to jelly while the other stays nearly unbeaten. The two pulps will give completely different formations, and the same holds true for color reversion and other properties.

Considering individual fibers, as Dr. Giertz mentioned, there may be chemical differences, for instance in lignin and hemicellulose content. Now what state are the hemicelluloses in after purification? They may or may not be decomposed. For example, with a bleached sulfite pulp from ponderosa pine, there may be very great losses in folding endurance when the wood is chipped with an ordinary chipper, as compared with wood cut by hand. If you take the same pulp with the large loss in fold, and screen it, the loss is eliminated entirely. This is because the screening eliminates about 7 to 10% of the fine debris which makes the stuff brittle, perhaps because of the form of the hemicelluloses after the purification reactions.

Now, about bonding. Nobody knows exactly what kind of bonding you get with these more-or-less decomposed hemicelluloses. Sometimes you certainly get low tear, because the paper is too dense and glued together too tightly. If the fines are eliminated, the tear goes up.

So I believe that in studying these problems, more attention should be paid to fiber size distribution, treatment of the wood, and also to the so-called "fine structure" of the cellulose. We know today that the cellulose fiber has several layers, called S1, S2, etc. Sometimes the S1 layer gets separated during cooking, and in other cases, it doesn't. There may also be further effects on this layer during bleaching, but nobody knows just what has happened to it. Sometimes you can screen it out, particularly after some beating.

These are some of the problems which I believe should be considered in further studies.

Dr. Whitney: I think your comments are good. The fine structure of cellulose, and the specific location of various materials, are pertinent questions. Does anyone on the panel wish to comment on this?

Dr. Hartler: I would like to return for a moment to our previous subject. At our laboratory we certainly believe very strongly in the necessity of applied research, development work, as well as, I would like to say, more pure research, fundamental research. We have a setup in Stockholm which covers both these lines. It was supposed from the beginning that the fundamental research group should accomplish results which should be brought further by the applied group, and this certainly has worked out very well in many cases. However, we have found that in many other cases it has to be the other way around. The applied group finds out something and this creates new areas where fundamental research has to be done in order to clarify and possibly utilize all that can come out of this more empirically-found effect. We have thus found that there must be a very intimate cooperation, not only that the applied groups take from the fundamental but also that fundamental groups have to take up things that have been found on a purely empirical base and do further work with them.

Dr. Whitney: This is a very pertinent comment. There is a question here from Mr. Drice which is essentially the same as one I was going to ask. He asks Dr. Rapson, "Isn't the solution to your application of chemicals problem the suspension of pulps in gas rather than in water?" I was going to ask about the possibility of gas-solid phase reactions for bleaching. Mr. Drice, do you want to add to this?

Dr. Drice: I might make a few additional comments. I was intrigued with Dr. Rapson's description of current chemical mixing in which pulps go this way and that way and the other, and in my mind, I can't possibly conceive what the equipment manufacturers are going to do about this which will achieve lower capital investment in equipment and also the desired uniformity of distribution of the chemical as long as we persist in running from 6 to 30% pulp consistency. I just wonder whether maybe we shouldn't get at this thing on the basis of humidity controlled fibers dispersed in a gaseous phase. Maybe the bleaching agents should be gas too.

Dr. Rapson: Very good. There is an abandoned patent of Charles Wayman and Rapson on bleaching rayon with chlorine dioxide gas in which the humidity of the rayon needs to be controlled at a certain point, and it works very well. The problem of course is to get equipment to carry out this reaction. I see the same thing exactly with respect to chlorination. I made a remark the other day that may have been

misinterpreted. I said that you couldn't get enough chlorine into the water to carry out a chlorination at ultra high consistency. I meant in one batch, but if you can put water and pulp together at high consistency then have it go through a chamber of gas, as the chlorine is used up more chlorine will dissolve in the water, and this is very good. That's why I say it's up to the equipment manufacturers. Anybody can do this in a test tube but who can do it yet on a large scale? I think it can be done with a thing like a Rotopulper. Something has to bring the gas and the solid into intimate contact and anybody that works in the lab knows how hard this is with any kind of solid, with any kind of heterogenous reaction. It's hard enough with liquid. How do you propose to do it with gas?

Dr. Drice: I have no axe to grind for the equipment manufacturers particularly, but I must disagree with you, Dr. Rapson in that I don't believe that this research should necessarily be supported 100% by equipment manufacturers. I think there are other people involved. I know how difficult it is for an equipment manufacturer to justify venture capital for research and development, to provide equipment for a process which isn't even on the horizon. Where is his guaranteed market which presumably his stockholders must have before he can commit the venture capital? I have a real suspicion that this kind of revolutionary changes in our processing, perhaps will come to us from across the ocean like so many other things. I don't know quite how they finance things over there, but apparently they do.

Dr. Rapson: I didn't mean the equipment manufacturers should pay for the research. I meant the equipment designers and creative thinkers should dream up the apparatus.

Dr. Whitney: Hans, are we going to get radically new bleaching techniques from overseas?

Dr. Giertz: I don't know about any new techniques for gaseous chlorination. I would, however, like to say something more on chlorination in the gas phase. In the chlorination reaction, we have both the pure substitution, or chlorination proper, and oxidation. Everything which presses the chlorine hydrolysis equilibrium over to the chlorine side is advantageous for chlorination. So, making the solution more acid means a better chlorination. But this is no way to follow, in order to get better chlorination, because the pulp becomes so acid in the ordinary chlorination operation that making it more acid within the range which is technically possible, doesn't favor the reaction very much. But it might be of interest to start with an acid fiber, and not with a slightly alkaline one as in sulfate bleaching.

Now back again to gas chlorination. If we have a high density pulp and gaseous chlorine, much more of the chlorine will be as Cl_2 and I know from experiments from my time in Stockholm that this gives definitely a deeper chlorination. The amount of residual lignin after this kind of chlorination and an alkaline extraction is on a lower level than any kind of water chlorination. And the pulp is not attacked noticeably.

Dr. Patterson: We already have in the industry at least two examples of gaseous reactions. The first one is in viscose aging where the alkali cellulose is allowed to react with gaseous oxygen. The second one is more or less with us in the form of vapor-phase sulfites in neutral sulfite cooking, where part of the cooking liquor is drained off and the reaction is allowed to proceed in the gaseous phase. I think there was also a patent for viscosity reduction using gaseous oxygen, by some of the dissolving pulp people. I'm all in favor of what Mr. Stevens said earlier about sharing some of this information.

There's one other possible problem here with regard to this work in gaseous phases. First of all, we need reliable equipment for handling high consistencies, which must come from the equipment suppliers because we can't engineer and design these things ourselves. And certainly, working in the gaseous phase, we need to come to a liquid phase sooner or later to dissolve out the reaction products, otherwise, we will block any further reaction.

Dr. Herbst: I have two comments about this. One is that what has been called during the last few minutes the gaseous reaction is only a gaseous reaction through an optical illusion. Certainly the aging of alkali cellulose occurs essentially in a liquid medium. All we have is alkali cellulose crumbs and the reaction occcurs entirely in the liquid phase, and the same is true for the vapor-phase cooking process. I think this is a gross misnomer and that cooking takes place in a liquid phase. In addition, I would like to ask Dr. Giertz if the advantage of a dry chlorination in practice would be the elimination of a tower—still an additional drying machine would be required to get the pulp dry after the cook, wouldn't it?

Dr. Giertz: No, I don't mean to have a completely dry pulp. If so, no reaction will take place. The pulp should have, I would assume, a dry content of 20 to 40%. Technically, this would require a filter with a press roll and then some kind of shredding machine.

Dr. Herbst: Now my second comment refers to Dr. Rapson's statement about mixing. I couldn't agree with him more, but I'm a lab man and I don't know if my ideas have any validity in practice. It seems to me that the way to get mixing is to operate at the consistency at which there is a small amount of free water and to run the pulp as a web or a sheet through a series of rollers which act like squeezers. We would have a pass of maybe a half a millimeter or a millimeter and this sort of squeezing action might provide a very cheap method of causing the liquid to pass through the fiber along a path of roughly that kind of length.

Dr. Whitney: I think your comments both are excellent. I don't think anyone would disagree with the feeling that the reaction undoubtedly is not gaseous or not a solid-gas reaction. But the material might be supplied in gaseous form, as we all agree.

Dr. Rapson: There's a great deal of values in this idea of doing all the bleaching reactions on a web of pulp at high consistency in a continuous system of a series of baths and rolling screens. Do the whole bleaching process this way.

Dr. Sarkanen: I would like to make a short comment concerning gaseous chlorination. It was well known in the old times that you can bleach cellulose with gaseous chlorine in the dry state. The only trouble is that it takes a very long time and the reason is that you need a polarizing medium in order to get the rapid ionic reaction. As far as the chlorination with moist pulp is concerned, I think the trouble is that you have a very high concentration of chlorine and you might get local overheating and local overchlorination. I don't know whether anybody has tried this but it would seem to me perfectly feasible to dilute the chlorine with an inert gas to cut down the rate of the reaction and avoid overchlorination. Before I stop, I would like to make a comment on Dr. Giertz's comment. He spoke about substitution and oxidation as the most important reactions in chlorination. We believe that the substitution, in the normal sense, is a waste of chlorine which does not help the disolution of lignin. The effective reaction is electrophilic displacement which however is formally a substitution reaction and which is measured as a substitution reaction.

Dr. Whitney: I have a question for Dr. Hartler from Mr. Meyer. He says, "Is the rate of brightness reversion higher if a given pulp, groundwood, sulfite, or kraft, is bleached to a higher brightness level? Is the final aged brightness level higher if the same pulp has been bleached to a higher brightness level?" Mr. Meyer, would you care to elaborate?

Dr. Meyer: Well, I agree that the tendency nowadays is to go to higher brightness bleached pulps, and if, as was shown on the blackboard, the tendency for the higher brightness pulps is to come down to the same brightness level after

aging, then there does not seem to be much sense in going to the extra cost of bleaching. The only justification would be if the final aged brightness of the pulp that has been bleached to a higher level actually remains at a higher level after the aging.

Dr. Hartler: I am not aware of any studies that have been made on the rate of brightness reversion. We have not done any such investigations ourselves. However, I think that there is no reason to believe that the high brightness pulp should revert faster than the low brightness pulp. In my preliminary statements I mentioned that a high brightness pulp that also has a fairly high color reversion is definitely not better than a pulp with a lower brightness also having a lower color reversion, but if you have a high brightness pulp and at the same time a low color reversion you certainly have accomplished an improvement in quality.

Dr. Spinner (University of Toronto): Actually, when one is up in brightnesses of 80, 85, and higher, I think that there's no relation between reversion and brightness as such, as such, but that if you have achieved the high brightness in the wrong way then of course you find high reversion. And in fact, you can get very bright pulps and provided you have eliminated those things which cause reversion, you can have a bright pulp with a minimum of reversion.

Jack Kilborn, (International Paper Co.): I'd like to ask Dr. Hartler: In your slides you demonstrated that extracted pulps had lower pc numbers than unextracted pulps. What was the solvent used in this extraction? Have you observed different effects with different solvents and is it possible that with the proper combination of solvents you could completely free pulp of undesirable so-called resins and thus eliminate brightness reversion?

Dr. Hartler: In the experiments that I refer to we used a 50-50% by volume mixture of ethanol and benzene as a solvent. We didn't try any other solvents and I do not therefore know the possible influence of different solvents. It is known that a specific solvent usually does not dissolve all the extractives in the pulp and also that different solvents extract the extractives to a varying degree. I think that the question you raised is very pertinent and I also hope that we may have a chance to study this problem sometime in the future.

Mr. Kilborn: I think we refer to extractives very vaguely. We call them resins as I did a moment ago. Between hardwoods and softwoods there's quite a difference. We've even experienced with repeated extractions, the TAPPI methanol-benzene procedure, that you get resins for maybe ten different extractions. So I just wondered if you completely removed these resins, maybe with 10 or 12 extractions with the proper extractants, could you eliminate the reversion?

Dr. Hartler: I do not know whether or not it is possible to completely eliminate reversion by making a proper and complete extraction of the extractives. However, I think that this is not possible. The carbohydrate material certainly also has an influence.

Dr. Rapson: We can make a 93 brightness pulp that will drop to 80 on heating in the oven at 105°C. for 18 hr. We can also make an 87 brightness pulp that will only drop to 86. Also, in striving to go from, say, 85 brightness to 87 brightness with hypochlorite on a kraft pulp, you can introduce tremendous color reversion. If the pH is too low, you can gain 2 points and lose 8 points in aged brightness.

George Day (Brown Co.): During the war we were by law supposed to bleach to not over 75 brightness. Nobody had eye strain so far as I know. The magic number used to be 80. Now it's 90. Maybe next year it'll be 110. Academically, it is quite interesting, but to my mind it has almost no practical significance. In our own paper mill, when the brightness level gets up to 91 or so, the papermakers put black in the furnish to tint it back and get the desired opacity.

Jumping back for a minute to this gas phase reaction, I might mention that the gas phase nitration of cellulose is a very easy technique. You don't get all the by-products which you do in the liquid solution. And it is very easy to run the nitrogen content right up to the theoretical ceiling of around 14 1/4%.

Dr. Rapson: I said yesterday the same thing that George Day did now. I've never been an advocate of higher brightness. I still am not but as long as people ask me how to do it, I'm still going to do research trying to make higher brightness. But I agree with you. There's no sense in it.

Dr. Whitney: Well, if you're trying to make higher brightness, Howard, I've another question for you from Mr. Meyer of ICR. He says: "Please comment on the possibility of raising the final brightness level by cleaning the unbleached pulp in centrifugal cleaners before bleaching, or alternately the possibility of obtaining improved strength and lower chemical cost for the same brightness. Would such cleaning affect the amount of brightness reversion?"

Dr. Rapson: This is quite so. You can bring about a big improvement in everything if you take the ray cells out of pulp. Yes, by centrifugal cleaning we can save bleach, we can get better strength, we can get better brightness, better color stability as Dr. Hartler showed by removing ray cells is usually too great for the advantages gained. It's all a matter of the relative value of the properties that you're after. But if cost is not a significant factor, then I would certainly fractionate out all the ray cells by whatever devices are available and then go on with the bleaching. We'd make better quality but the cost would be rather high.

Dr. Hartler: It was reported that somewhere in the States centrifugal cleaning of groundwood had been made before bleaching with peroxide and zinc hydrosulfite. Do you actually get some points higher final brightness in this case?

Tony Yankowski (Kimberly-Clark Corp.): You do get a higher brightness but it's because the dirt count is lower. Dirt usually interferes with the brightness meter, but actually as far as G.E. brightness is concerned, you don't get any higher number except for the effect of the dirt removal.

Dr. Hartler: One of the more fundamental questions in this respect that was brought up, was whether or not those particles that are removed during centrifugal cleaning give an improved bleaching behavior and color stability. The fraction of the pulp that by removal might give these improved properties are the parenchymatic cells which contain more lignin, more noncellulose material and definitely more resins than the rest of the pulp. However, in my experience these parenchymatic cells are not removed selectively during centrifugal cleaning and I would therefore expect that centrifugal cleaning in general has little influence on the bleaching behavior and the color stability.

Mr. Patterson: We have tried it. You can't get them out by centrifugal cleaning. You can only get them out by means of an inclined screen.

R. G. Meret (MacMillan, Bloedel and Powell River): We had somewhat the same experience at Powell River. We have screened centrifugally the groundwood pulps several times for different reversion purposes, and we never got any brightness increase. Just elimination of some dirt.

Dr. Whitney: I have a request here from Rick Salvesen of Marathon. He would like to comment on the subject of pulping and bleaching. This is a broad subject.

Dr. Salvesen: A little earlier this afternoon somebody said it would be a wonderful thing if you could take all these fancy bleaching chemicals and throw them together and bleach in a mixture. And then Howard whispered that we should take the bleaching mixture and put it in the digester. Well, this was said jokingly but actually, I think it should be remembered that this is actually being done. I'll just mention a few examples. First, regarding putting the bleaching agent in the digester, is the work that was done by Professor Jayme at Darmstadt, where he actually had hydrosulfite present in connection with an alkaline cook. Now

I never heard of anybody doing this commercially, but maybe our visitors from Germany can tell us whether this is beyond the test tube or laboratory stage. But in his publication, Professor Jayme reported that, from such an alkaline cook, he got an easily beaten pulp that could readily be bleached to a high brightness by a simple three-stage bleaching process. Now this is one example.

Another example that I know is a reality is the so-called Sivola process that now is operated in Finland. We have a representative here from the operating staff of at least one mill where this goes on, and in a discussion I had with him, he pointed out that part of the cooking process is actually a caustic extraction stage of the bleaching operation. Or it can be used as such. So there are two processes where actually part of the drudgery, you might say, of the bleaching operation has been taken over in the digester. It seems to me a logical thing to do.

Now our friend Hartler here has been making alkaline cooks with sodium borohydride. So there is another case.

Dr. Rapson: I'll add a fourth one. Dr. Rhys is here and he has a method of pulping with sodium chlorate and hydrogen chloride which pulps and bleaches in the same stage.

Dr. Hartler: As far as the addition of hydrosulfite to the kraft cooking liquor is concerned it was found that, when this chemical was applied under technical conditions, there was an increase in brightness on the unbleached pulp, but that the pulp yield and the rate of delignification and also the strength properties were substantially unchanged. I would like to make reference to an article by Regnfors (*Svensk Papperstidning* 1957, page 178).

When sodium borohydride is added to kraft cooking liquor the increase in pulp yield is very substantial. At the same time there is a small increase in unbleached brightness and also the effect that the unbleached pulp is more readily beaten. However, the main goal when applying sodium borohydride in connection with kraft cooking is not to obtain increased rate of delignification or to obtain higher pulp brightness but to have a higher pulp yield at the same lignin content in the pulp. It is possible to obtain 15% higher pulp yield at the same lignin content.

A. Van Koeppen (Western Michigan University): Using hydrosulfite in cooking was successfully applied at Darmstadt, but, if I can remember the correspondence that I have with the university, they got a higher initial brightness, a slightly higher yield, but this study was never commercialized because of economical reasons. Too much hydrosulfite had to be used. This pulp was more easily bleached than the ordinary kraft pulp. Economics was only one factor.

Dr. Whitney: Thank you. Any other comments on this general subject of combined pulping and bleaching?

Dr. Drice: Dr. Hartler, could you please state again your comments with respect to the sodium borohydride added to the digester? Did you say that you got a 15% increase in cellulose yield with no appreciable difference in the lignin content?

Dr. Hartler: Yes, you are right insofar as the effect of borohydride in kraft pulping is concerned. I would have liked very much to discuss this a little further, however, this may be left to a pulping panel discussion.

Dr. Drice: Just one more point. Was that a kraft cook or a sulfite cook?

Dr. Hartler: The cook I referred to was a straightforward kraft cook and the pulp yields were compared at the same lignin content obtained through interpolation in a yield Roe-number diagram.

Dr. Rapson: Didn't that take 2% borohydride on wood, if I remember correctly?

Dr. Hartler: For the effect I mentioned, it takes about 2%.

Dr. Rapson: Two per cent on the pulp. For quick calculation $120 a ton to save 15% of the wood. This is what's stopping these things, you see. That's why I said we've got to get the cost of chemicals down.

Dr. Hartler: That's right.

Dr. Sarkanen: I have a very short comment on the principle of putting the bleaching agent in the digester. If you do this, you are going to bleach the waste liquor too and use quite a bit of the bleaching agent for that. Nowadays you are able to market the waste liquor, so you shouldn't do that. So the only principle you can use is to inhibit the formation of additional chromophore groups in the residual lignin. Actually, you shouldn't call this bleaching, but I think in principle this approach is practically dead.

Dr. Whitney: Thank you. What about hypochlorites? Is it not true that bleaching in the hypochlorite stage is a much slower process than chlorination and some of the others? If we're going to speed up the overall bleaching sequence, mustn't we either speed up the hypochlorite stages or else eliminate them?

Dr. Rapson: Hypochlorite bleaching can be carried out time in the proper way. The only reason we carry it out at a long time is this is the kind of tubs we have in the mills.

Dr. Whitney: Well, let's change the tubs then.

Dr. Rapson: Right. That's what I meant by my statement that it's up to equipment designers. We can solve the chemical problems. It's the equipment for carrying out these fast reactions that needs development. I believe that hypochlorite bleaching can be carried out at 100°C. or even higher but it's got to be done in a very few seconds. And that means that in that short time you've got to get the liquid uniformly distributed among all the fibers.

Dr. Whitney: What about cellulose degradation at these temperatures?

Dr. Rapson: Cellulose degradation is a function of time and temperature and concentration of hypochlorite and no other factors.

Dr. Whitney: pH?

Dr. Rapson: Sorry, yes, pH is the most important variable, in all bleaching processes. However, to get back on the track, there is no reason why you can't bleach at high temperatures. It's a question of whether you can get the chemical in, get it mixed, and get the products out fast enough. This involves equipment design.

Dr. Whitney: You said that cellulose degradation is a function of temperature. Still, is it not significant at 100°C.

Dr. Rapson: When you heat for a very short time, seconds maybe.

Dr. Giertz: Howard, I think you've gone too far now. It is not only necessary to change the equipment. You have also to change the fundamental laws of speed of diffusion and speed of reaction. It is quite right that the first reaction in hypochlorite bleaching is very rapid. But after having reacted that part of the lignin which was open for reaction, we have to dissolve it in order to proceed further and this is a slow diffusion reaction. If we want to carry out the final bleaching in one stage, which is a great advantage of hypochlorite bleaching, then we have to wait until the reaction products have a chance to come out of the fiber. There is no reason to speed up the reaction with higher temperature, because with temperature diffusion increases only slowly, whereas chemical reactions, such as attack on the fiber, are favored much more. Therefore, I think it is no solution to go up to high temperatures if you want to get brightness without fiber attack with the hypochlorite bleaching in one stage. Higher pH, however, which decreases the chemical reactions, might allow higher temperature, and at the same time the higher degree of swelling will favor the diffusion reactions.

Dr. Rapson: You're quite right. I exaggerated a little to drive the point home. Nevertheless, it has already been clearly shown by some Swedish work that as long as you shorten the time of hypochlorite bleaching you can go up to high temperatures, 60 or 70°C. anyway. People often

ask me what is the maximum temperature we can use for hypochlorite. I always reply that in the old days we said 35°C. and today we really don't know.

Dr. Herbst: The big problem in hypochlorite bleaching is not time. It is selectivity. There are at least three reactions which are of importance: viscosity reduction, brightening, and the formation of functional groups. Now there is a tremendous number of conditions which can be altered to make this reaction go one way or another. I'd like to make a simplifying definition first. I'd like to define good conditions for paper pulp bleaching for the purposes of this discussion as those conditions which give a high viscosity at a given target brightness. Now I don't want to get drawn into an argument on the relationship between viscosity and strength, mainly because I don't know very much about it. However, one would think that in an industry such as ours, the question, "which temperature gives the best reaction under these conditions and under these definitions," would have been long settled. This is not the case. There is no single answer as to what is the best temperature to get the highest viscosity at a given brightness. An illustrative example of the complexities which this subject offers is the following: I posed the question some time ago, "is 50° a more favorable temperature than 25°?" Now this is not an answerable question for the following reason. You have three variables. You have the time, you have the temperature, and you have the amount of bleach added, or the amount of residual bleach. [I'm referring now to the optimum H. which is fairly well established as being between 9 and 10.] If you change one of them, as we have said that we would change temperature, you must necessarily change the others. So we carried out some experiments on a pulp from one of our mills in which we did three experiments: (a) a control at 50°C.; (b) one in which the temperature was lowered to 25°C. and the time was kept constant by an increase in the amount of bleach added; and (c), a similar experiment at 25°C. in which the time was lengthened and the residual was kept constant. Well, the answers were opposite for a given pulp in those cases. In one case, 25 was a better temperature and in another 50. Different experiments with different pulps gave different relationships for these questions. I'm merely mentioning this as an illustration of the complexity of this sort of thing.

Dr. Whitney: Thank you very much, Dr. Herbst. I think your comments are excellent, and illustrate the fact that we need to have more fundamental information about the kinetics of not only the bleaching reaction but the other reactions which proceed.

Dr. Rhys: I just wanted to mention that if you have the same quantity of hypochlorite the consistency is very important because you get a different proportion of chlorination and oxidation. This is, for example, the reason why chlorination is saving 25% of chlorine as against one-stage bleaching. So this means that it could be also different for different stocks. What proportions, what temperatures, because higher temperature gives you higher oxidation. Of course, if you go down in pH you get more substitution, so at a certain point you get just an excess of chlorine used for substitution without any use as was mentioned before, and this is not economical. Also, if you have too high a consistency with the higher formation of hydrochloric acid because of the substitution, you can harm the pulp.

Dr. Whitney: I think this comment is pertinent. Obviously the type of reaction depends on the molecular and ionic species present and these are functions of concentration. It's been amazing to me over the years that relatively little is known about the ionic equilibria not only in bleaching systems containing pulps but just in aqueous solutions of the bleaching agents. We're woefully ignorant about what is in the bleaching solutions.

Dr. Rapson: Roy, this is true for some reagents but for chlorine it's pretty thoroughly worked out and Carlton Dence has it very nicely in his chapter for the bleaching monograph. I think it's an excellent piece of work.

Dr. Whitney: It is worked out better for chlorine than for any other bleaching agent. But we need much more information, in my judgment.

H. Freedman (Penobscot Chemical Fibre): I'd like to switch the spotlight from what we've been talking about to something which I hope will fall within the scope of this meeting. Of tremendous interest to purchasers and producers of market pulps are the effects of irreversible hornification as the pulp is dried on a machine. These effects are shown by the fact that the dried pulp even after beating never does quite attain the properties it had before the pulp was dried on the machine and as such it can undo to a great extent a lot of the pulping and bleaching which is achieved in the process. I wonder if it would not be suitable for us to place a little more emphasis on this somewhat neglected part of our bleached pulp manufacture.

Dr. Whitney: Thank you. Does anyone wish to comment on this?

Dr. Rapson: This is a question that just can't be answered yes or no. This would require a rather significant amplication and it is a little beyond the question of bleaching. The hornification which occurs on drying is present in varying degrees for all pulps. It is a very important matter since, if we repulp dried pulp, we can't bleach it in the same manner. For dissolving pulps this is a critical question, so my reason for not saying anything was that I did not want to launch into a long discourse on it.

Dr. Whitney: Thank you, Howard. Any further comments of a rather brief nature? Van, do you have a last minute comment?

Dr. Van den Akker: No. Thanks just the same.

Dr. Whitney: Jack, you've been let off easily this afternoon.

Dr. Stevens: I've been sitting back here listening to this discussion on bleaching and it becomes apparent to me that the majority of opinion of bleaching is to obtain whiteness or brightness of pulp fiber. From my point of view, this is rather a secondary goal and I would say that the members of TAPPI as a whole might do well to broaden their outlook a little bit and look more at the purification of pulp fiber in relationship to pulp brightness. And they may be surprised at some of the fine points that come out of such an approach.

Dr. Rapson: Van made a point that I want to just mention. He said that if we compared pulps with magnesium carbonate we should get a reflectivity of very nearly a hundred per cent by some coincidence that wasn't quite clear to me, but we have made pulps in the laboratory which are 99 or better reflectivity compared with magnesium carbonate. In fact pulp has been shipped from mills that I'm familiar with at 98.5% of the reflectivity of magnesium carbonate as measured on the Hardy spectrophotometer in a very large tonnage. Jack Stevens might want to say something about that.

Dr. Van den Akker: If I said magnesium carbonate, I mis-spoke. I intended to say magnesium oxide. The reflectance of magnesium carbonate is usually less than that of MgO; also, the integrating sphere geometry of the Hardy yields a result higher than the standard brightness.

Dr. Rapson: Oh, well then, deduct about 1.8%.

Dr. Van den Akker: No, anything from that to about 6%, depending on the samples of the magnesium carbonate.

Dr. Rapson: Others can speak for themselves, but we carefully check our samples of magnesium carbonate against a fixed standard, and then our ultimate standard of course is the calibration system at The Institute of Paper Chemistry. We always go back to that so when we calibrate the G.E. brightness against our results on our method of measuring against magnesium carbonate, by making a correction of 1.8% over quite a wide range, we come in line with the samples

from the Institute. I haven't measured any samples in this 96 to 99% brightness range, I must admit. You may be quite right in that very high range.

DR. WHITNEY: I should like to thank all of you for participating so well this afternoon, and I want particularly to thank our panel members. I think that we may not have solved all the bleaching problems this afternoon. However, it does seem to me that we have come to general agreement that there is room for audacious thinking, and there is a possibility of radically new approachs. While we may have brainstormed some of them to a very minor extent, this certainly is not research. We can't find the answers to some of these questions we've been asking until someone goes into the laboratory and does some real hard work. In addition to the fine empirical and applied work which is going on and must continue, I say again we must step up our volume of fundamental research, better to understand what is really going on in these systems of ours. With this, I shall turn the meeting back to Dr. Kraft for his closing remarks.

DR. KRAFT: Roy, the applause of the audience has shown that you and your panel with your lively and very informative discussion has given us a very fruitful afternoon. Well, gentlemen, that's about it. Except for taxes, all things come to an end and we have reached this point in our conference. We have had very many hours of lectures and debates and each of us I'm quite sure, has learned something. You were a wonderful audience, most responsive, and receptive even during such discussions which were highly theoretical. I wish to express to you my sincere appreciation and those of my colleagues. Very special thanks goes to the speakers and the panel members who have worked so hard to assemble so much information and knowledge and pass it on to us. I'm very proud of congratulating all of them for a job well done.

We pay tribute also to the moderators who kept the proceedings on beam and on schedule and to the attendants who were quite efficient. In the final analysis we owe all this to the excellent work done by our technical program committee and I hope you will join me in complimenting Dick Auchter and his two assistants. And last but not least we are much indebted to Herb Teeple who set the stage for our meetings. I know how much work was involved. At times, I saw that he had perhaps the most complex job of all of us, particularly operating this projecting machine. He deserves great credit for all his fine preparations and for conducting the mechanics of the meeting so wonderfully well.

Now I should condense results of our meetings in a few sentences to stress the high lights, however, the information given by the speakers and your contributions were so massive that their reduction into a résumé that could be produced within a reasonable time is momentarily not feasible. This, on the other hand, makes it easy for me because I can properly rightfully say that we know there is much energetic work going on and that we have good hope for substantial progress in the not too distant future.

When I said a minute ago that the conference had come to an end, I didn't really mean it in the full sense of the word. It is true, we all go home, we all leave Chicago now and return to our old jobs, but this isn't the whole story. The infusion of ideas, new ideas into our minds and the more complete understanding which every one of us will take with him will influence our thinking and will find its way into our own and our company's planning. On Tuesday, I mentioned that we had with us a lot of people who were responsible for the development of pulp purification for the last maybe ten or twenty years. Now I may similarly say that we have here with us or had with us most of those who will chart and steer the course for the next five or ten years and they will now go home and will utilize, I hope, I trust, what they have learned here.

Therefore, we should be well on the path of progress. Maybe it is gradual but I think it is practically guaranteed and if this thought is valid, then the conference has achieved its main objective. And again if this is so, I may be allowed to recommend that you people keep up your interest in the work of this committee. There will always be problems. We have heard about very, very many of them this afternoon and we need men to tell us how to cope with those and to show us where we want to go. So let us develop this committee into a focal point of our continued efforts so the day will not be distant when somebody will second the motion which last night was graciously made that some time we meet again.

And in conclusion, I wish to our friends from overseas a very fruitful and pleasant stay in this country, and when they go home, please give our regards to your colleagues and to all of you, many, many thanks, and Auf Wiedersehen.

LETTERS TO THE EDITOR

Drying with Air

To the Editor, *Tappi*

In connection with the paper, "A Theory of Drying with Air," T. A. Gardner, *Tappi* 43: 796–800 (Sept. 1960) it is believed the following items from the literature may help clarify the theory behind drying with high velocity air jets:

1. The centerline velocity of a jet is given by Albertson *et al.* (*Proc. ASCE* 74: 1571–1596 (Dec. 1948)) using Gardner's terminology it is:

$$E = 2.28(D/y)^{0.5} = V/V_0$$

2. The velocity and direction of a jet after impingement against a normal surface were given by Rankine ("Applied Mechanics," 21st ed., 1921, p. 592) i.e., same velocity but parallel to surface.

3. The heat transfer for parallel flow was given by Powell (*Trans. Inst. Chem. Engr.* 18: 36, 1940):

$$hL = 0.207L^{0.77}(1 + 0.0189G^{0.85})$$

Thus, for Gardner's drier, the average velocity = 7050 f.p.m. and:

$$h\left(\frac{0.5''}{12}\right) = 0.207\left(\frac{0.5''}{12}\right)^{0.77}[1 + 0.0189(0.052 \times 7050 \times 60)^{0.85}]$$

$$h = 40.5 \text{ B.t.u.(sq. ft. } \times \text{ hr. } \times \text{ °F.)}$$

this compares with 42.5 to 55 quoted by Gardner.

G in the above equation is the mass air velocity in lb./(hr. $\times$ sq. ft.).

4. Heat transfer for a so-called "typical drier" is given as $C_1G_s^{.078}$ by Friedman and Mueller (Proc. General Discussion on Heat Transfer—ASME, 1951, pp. 138–142); a correlation* of their data gives a value for C_1 of 0.15 in Gardner's example. G_s is the superficial mass velocity. Therefore:

$$h = 0.15(0.052 \times 10{,}000 \text{ f.p.m.} \times 60 \text{ mm./hr.} \times 0.2''/8'')^{0.78} = 27$$

versus 12.2 to 22.2 quoted by Gardner. (*Note:* A properly designed unit of this type would use 40% of this amount of air and give an h of 23.)

5. The damage caused by the heels of girls' shoes is not due to their weight but the intensity of pressure. Likewise the damage due to an air jet is related to the maximum intensity of pressure developed at the surface of the web.

* Unpublished.

$$F/A = \rho V^2/2g$$
$$= 7.8 \text{ lb./sq. ft. for "Typical"}$$
$$= 11.0 \text{ lb./sq. ft. for Gardner}$$

6. The theoretical horsepower per square foot of drier is:

$$0.174A \cdot C_c(P^3/\rho)^{0.5}$$
$$\text{or } 1.3\ \rho V_0^3 A C_c \times 10^{-10}$$

where A is slot area per square foot of drier and C_c is coefficient of contraction, P is the pressure behind the jet in inches of water.

Substituting the values suggested by Gardner:

$$1.3 \times 0.052 \times 15{,}000^3 \frac{0.017}{1.000} \cdot 10^{-10} = 0.387 \text{ hp./sq. ft.}$$

for Gardner drier

And:

$$1.3 \times 0.052 \times 10{,}000^3\, 0.2''/8'' \cdot 10^{-10} = 0.168 \text{ hp./sq. ft.}$$

for "Typical drier"

Therefore, the Gardner drier uses 2.3 times the fan horsepower to obtain a 50% increase in drying rate. As mentioned above, however, the "typical drier" uses 2.5 times the optimum air volume and horsepower.

Very truly yours,

CHESTER E. ROSE
Senior Consultant
Engineering Dept.
Ansco Div., General Machine & Film Corp.
Binghamton, N. Y.

To the Editor, *Tappi*

The following are my categorical comments on Mr. Rose's letter of Nov. 11, 1960.

1. My impirical formula for centerline velocity was secured by several rigid tests on two nozzle sizes. The data were almost perfectly correlated by my formula which simply makes allowance for the so-called core flow of a jet leaving an orifice. Observations of smoke tests on jet flow showed core flow which looked like a short flame within the jet.

2. The velocity close to and parallel to the surface under the impingement area of a jet is not as great as the jet velocity. It accelerates rapidly from the stagnation point and becomes equal to the jet velocity as it leaves the impingement area. The impingement area of a jet is extremely important as heat transfer has been shown to be very high in this region, quite likely in the manner proposed in my paper. We have also scorched paper under the Gardner drier to test for variations in heat transfer. The stagnation lines were sharply etched on the paper and the burn color shaded off to nothing from the stagnation lines to approximately clear of the impingement area.

(Mr. Gardner is very correct in his item no. 2. The heat transfer under the center of a jet is very high. The local heat transfer coefficient under a circular jet has been reported by Vickers, *I&EC* 51: 967–972 (August, 1959). (C. E. R.).)

3. In view of the above and of fairly comprehensive tests made by us on drier arrangements (I intend to report these test results to the C.P.P.A. in Montreal, Jan. 24, 1961), the Powell formula does not apply. According to the tests a heat transfer coefficient of about 56 with 400°F. dry air would be secured by the Gardner drier design given in my paper. If the now known optimum design is used the coefficient would be 65 with the same power.

4. My present estimate of the typical drier design given in my paper would give an H.T.C. of 30 to 35. On the same power basis the H.T.C. would be 40 to 45. Our own tests indicate that this drier design is close to optimum based on the percentage of orifice area to surface area. Thus the present comparison based on optimum design and equal power input places the Gardner drier approximately 40% above the given typical drier.

5. The proper basis for comparison requires that any two units have optimum orifice area which appears to be constant over a large range and equal power. Thus, the orifice velocities are also equal. The impingement velocity of the smaller jets is lower, however. The mass of the stream is also much less which must reduce damaging effects. Simple intensity of pressure is rarely of much concern, especially considering the low magnitude involved here unless a large area is involved.

6. The air horsepower is of great importance in an air drier, and I should have been aware of this before presenting my comparison. The H.T.C. varies with horsepower input to the 0.24 to 0.26 power. Thus if on the same power basis the Gardner drier H.T.C. exceeds the typical by 40%, the typical drier would have to be supplied with $3^1/_2$ times more power for equal drying performance.

I wish to compliment Mr. Rose on his acquaintance with the literature and on his ability to use the information. I also wish to thank him for spending the time to prepare his criticism which I sincerely welcome.

T. A. GARDNER,
Pulp & Paper Engineering
Marathon, a Div. of American Can Co.
Menasha, Wis.

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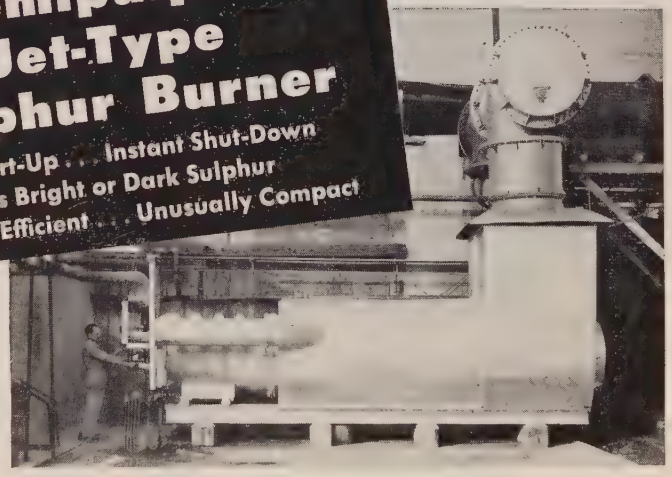

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LOCAL SECTION ACTIVITIES

Meeting Calendar

March, 1961

21 Golden Gate Section, Crown Zellerbach Bldg., San Francisco, Calif.

21 Pacific Section, Longview, Wash. Shibley Award Meeting.

21 Indiana District, Ohio Section, Marott Hotel, Indianapolis, Ind. Education Committee Meeting, "Who We Are and What We Do" (Indiana High School Science Teachers as guests), Dr. Alfred H. Nadelman, Western Michigan University.

24–25 Southeastern Section, Bon Air Hotel, Augusta, Ga. Tour of Continental Can Co. paper mill.

April, 1961

4 Chicago Section, Chicago Bar Association, 29 S. LaSalle St., Chicago, Ill. F.D.A. (Tentative, will hold if warranted).

6 Lake Erie Section, Cleveland, Ohio. "The Advantages and Disadvantages of Letterpress and Flexography."

6 Kalamazoo Valley Section, Inman's Restaurant, Galesburg, Mich. Visit to Michigan Carton Co.

7 Central District, Empire State Section, University Club, Syracuse, N. Y. Senior Night-Junior Awards.

7 Gulf Coast Section, Pine Bluff, Ark.

10 Pioneer Valley District, New England Section, Storrowton Tavern, West Springfield, Mass. Management night.

11 Metropolitan District, Empire State Section, 465 Lexington Ave., New York, N. Y. "The Reused Fiber."

11 Lake States Section, Mill visit—Neenah Paper Mill of Kimberly-Clark Corp. Dinner at Menasha Elks Club. Theme: Strength Evaluation of Pulps, also C. J. West Award.

13 Ohio Section, Tour National Cash Register Co. at Dayton, Ohio.

13 Northern District, Empire State Section, Hotel Woodruff, Watertown, N. Y. Joint meeting with Beaver Falls Chapter, A.I.C. "The Planning of a Technical Center," by K. A. Arnold, St. Regis Paper Co.

18 Indiana District of the Ohio Section. Plant Tour, Container Corp. of America corrugating medium mill, Carthage, Ind. Dinner at Durbin Hotel, Rushville, Ind. "Machinery of Paper—Part III—Beater Room Equipment," N. S. Balfour, Beveridge Paper Co.

20 St. Louis Section, LeChateau Restaurant, 10405 Clayton Road, St. Louis, Mo., "Paper and Ink Relationships," John C. Brazrell, Champion Paper & Fibre Co.

27 Delaware Valley Section, Engineers Club, Philadelphia, Pa. Program on wet end retention by The Institute of Paper Chemistry.

May, 1961

2 Chicago Section, Chicago Bar Association 29 S. LaSalle St., Chicago, Ill. "Structural Design: Corrugated & Folding Cartons."

4–5 Pacific Section, Harrison Hot Springs, Canada.

5 Central District, Empire State Section, Syracuse, N. Y. Ladies' Night.

9 Golden Gate Section, Claremont Hotel, Berkeley, Calif.

11 Northern District, Empire State Section, Hotel Woodruff, Watertown, N. Y. Annual Ladies' Night.

11 Ohio Section, Hartwell Recreation Hall, Cincinnati, Ohio. Ladies' Night.

11 Lake States Section, Green Bay, Wis., Hotel Northland, Dinner meeting during National Symposium on Pulp & Paper Instrumentation. Theme: Instrumentation and Its Future.

16 Indiana District, Ohio Section, Marott Hotel, Indianapolis, Ind. "FDA Regulations—Current Status."

19 Metropolitan District, Empire State Section, Tavern on the Green, New York, N. Y. Ladies' Night.

19–20 Southestern Section, General Oglethorpe Hotel, Savannah, Ga.

25 Delaware Valley Section, Engineers Club, Philadelphia, Pa. E. J. Albert Award.

25 Kalamazoo Valley Section, Gull Harbor Inn, Gull Lake, Joint PIMA-TAPPI Recognition Night.

25 Delaware Valley Section, Philadelphia, Pa.

26–27 Gulf Coast Section, New Orleans, La.
Virginia-Carolina Section, Dinner Meeting and Mill Tour.

June, 1961

8–10 Empire State Section, Whiteface Inn, Whiteface, N. Y.

8–10 New England Section and Maine-New Hampshire Section. Joint Meeting. Wentworth-by-the Sea, Portsmouth, N. H.

10 Lake Erie Section, Cleveland, Ohio. Annual Dinner Dance, Greenbriar Restaurant, Parma Heights, Ohio.

20 Kalamazoo Valley Section, Gull Lake Country Club, Gull Lake. Joint TAPPI-PIMA fun day.

20 Indiana District, Ohio Section, Anderson Country Club, Anderson Ind. Fourth Annual Golf Outing.

September, 1961

21 St. Louis Section "Paper Mill Visit."

November, 1961

30 St. Louis Section.

June, 1962

1–2 New England Section, Chatham Bars Inn, Chatham, Mass.

7–9 Empire State Section, Whiteface Inn, Whiteface, N. Y.

June, 1963

6–8 Empire State Section, Whiteface Inn, Whiteface, N. Y.

Ohio

"Plastic Fourdrinier Fabrics" was the topic discussed by Charles A. Lee who was the featured speaker at the December 15th dinner meeting of Ohio TAPPI at the Manchester Hotel in Middletown, Ohio.

He began by reviewing the Huyck Corp.'s progress in developing "Formex" forming fabric since the idea was conceived in 1952 by the president of that corporation while watching a wire change on a paper machine.

After considerable research a pilot plant with looms and treating equipment was set up in Tennessee to produce the first wires. Some of the early problems encountered were to obtain a uniform weave, treat properly, and keep the strands in proper relationship. Later they had to overcome problems associated with actual use on the paper machine.

A little over one year ago they were in a position to move forward. A sales organization was established and commercial manufacture started. At present there are 12 installations in the United States, Canada, and Europe. A new manufacturing plant is being constructed in Canada and new plants are planned in England and other European countries.

Wires to date vary from 24 to 145 ft. in loop size. All are made to specific requirements. Applications include newsprint, kraft, glassine, and groundwood specialties. The fabric is being run on a continuing basis.

Some disadvantages that still exist are a stretch that occurs after installation and a tendency to narrow under load. The stretch amounts to $2^1/_2$ to 3%. It occurs during the first 4 to 6 hr. of use and is not a problem thereafter. However, its reoccurrence after each shutdown of a couple days or more is the only manifestation of the "memory" nature of plastics. This stretch is being compensated for by additional equipment.

Narrowing under load occurs in the vacuum section on a fourdrinier. For example on a 140 in. wide web, a $^3/_8$ to $^1/_2$ in. narrowing has occurred between the suction boxes and the couch roll. This has required the use of Mt. Hope rolls after the couch.

Advantages that have been experienced in actual use are corrosion resistance and equalized wear on both sides. The fabric can be turned over as is possible with felts. It is an endless woven loop and therefore has no seam. Due to the manner of weaving the cross machine strands take the wear. That feature has resulted in some rather unique operating experiences. On one occasion an old wire continued to run with a complete machine direction split. It was only noticed when the mark showed in the reel. On another occasion a 2 in. area of a wire was bound by some mechanical fault of another machine part. The 2 in. strip ripped free and remained stationary while the rest of the wire continued to run.

Another advantage is that the sheet releases more readily due to the characteristics of the plastic. Pitch has not been so much a problem as with metal. Damage during installation has been very rare. Actually the plastic can be roped as with felts. Wetting prior to installation improves this flexibility feature. Handling like a felt has saved as much as $3^1/_2$ to 4 hr. on a wire change.

Also on one occasion a mechanical failure caused a wire to rope and pile up at one side of the machine. After the failure was repaired the wire was put back in position and continued to run satisfactorily.

Several unusual problems have evolved in using the wires. First models had a drainage area equal to that of metal wires. The drainage rate was found to be twice that of the metal wire. Therefore, the open area was reduced 50%. This characteristic permits a wide range of drainage rates but also poses a problem of determining the proper rate for a specific application. The tendency has been for mills to ask for higher drainage rates but this is discouraged. It has been found best to try the plastic wire at the usual drainage rate before trying to improve this feature.

Vacuum box modifications have also been an area of unusual developments. The plastic has been found to permit the use of such materials as stainless steel for flatboxes. One installation of stainless showed no wear in a 1-year trial.

Huyck Corp.'s main interest has been in fourdrinier application. However, some consideration has been given other areas and plans are to look into other uses on cylinder machines, washers, and driers

In designing and developing plastic fabrics for various uses there are three main considerations; surface features, strength and abrasion resistance. For example in a kraft application, strength can be emphasized at the expense of other features. In other applications the need for a finer fabric means a compromise of those features more important to wire life.

In a vigorous question-and-answer period some other points were brought out. It is possible to repair holes in the plastic fabric successfully. As to the life of the fabric, it has run two to four times that of metal. The cost was approximated at 70% over metal. It has not been found necessary to sour out the wires but certain other specific cleaning procedures are recommended. Wires when worn out have showed the strength of the cross direction strands to be at 12 to 15% of their original strength. Sudden stops as with power failures will cause breaks. However, the plastic fabric has proved no worse in this respect than metal wires. The wires are designed for and operated at normal tension. In considering drier applications the wires are able to stand temperatures up to 375°F. Mr. Lee's final remark pointed out that plastic wires are introducing new methods and new technology in papermaking.

THOMAS H. WEISMAN, *Recording Secretary*

January Meeting

On January 10th, 145 persons attended the Ohio TAPPI meeting at which Merchant L. Cushing presented the following paper. The meeting was held at the Manchester Hotel in Middletown.

Some Recent Advances in Wet-end Additives and Implications for Future Research

Merchant L. Cushing

IT WOULD be quite presumptuous of me to come before you professing to bring you the last golden kernel of truth about wet-end additives for papermaking. It would be so firstly because we shall never reach a "steady state" of knowledge beyond which no man may venture, and secondly because others have quite recently summarized the latest findings and observations relating to this field and we have seen no major developments since the last literature discussions of this subject.

Let me then occupy our time with a progress report of work within our own organization which will be tied in with the current state of knowledge as we have had an opportunity to learn of it.

A little over a year ago, in September, 1959, the Indiana District of the Ohio TAPPI Section had the privilege of a talk by Swanson of The Institute of Paper Chemistry (*1*), in which he pointed out several factors which are essential in the development of the fiber-to-fiber bonding which is in turn the key to the strength and quality of paper and paperboard products.

Firstly, it was shown that the theory that the strength of paper resides in mechanical entanglement and frictional effects of the fibers and fibrils has now been largely disproved.

MERCHANT L. CUSHING, Head, Paper Laboratory, Applications Research, A. E. Staley Manufacturing Co., Decatur, Ill.

Secondly, the major importance of secondary molecular forces in the field of adhesion (here fiber-to-fiber bonding) was stressed. The residual attractive forces between molecules produce bonds whose rupture or formation involve energy changes of from 0.5 to 10 kilocalories per mole. These residual attractive forces are exerted in all directions from a molecule and are of three main types:

1. The orientation effect (Keesom force) which is of major importance for substances of high dipolar character. A special case of this effect is the formation of the hydrogen bond when a H atom is attached to strongly electronegative groups such as O, N, S, or halogen; and the H is shared between two such electronegative groups.
2. The dispersion or London effect which always produces considerable molecular attraction.
3. The induction or Debye effect which is small for most molecules.

The various phases of papermaking, which, in summation, result in a useful product, deal primarily with problems of adhesion and most specifically in all of our interests with fiber-to-fiber adhesion. Many observers and workers have been individually and collectively responsible for the presently well-accepted thesis that the main bonding force in paper and paperboard is the hydrogen bond. The current emphasis on the impact of the hydrogen bond in papermaking is as significant as the emphasis on neutrons, protons, mesons, alpha, beta, and gamma radiation is in nuclear weapons or nuclear science. We have uncovered the significance of the effect of small particles, acting over short distances, on the overall properties of matter in the bulk.

Thiesmeyer (*2*) at the First Forest Biology Conference in Seattle, Aug. 24, 1960, in a talk titled "Minute Differences Have Tremendous Consequences" spoke of the significance of small changes or small forces in many industrial or scientific ventures.

We have thus become able to examine the final product in terms of how its gross properties are affected by the niceties and balances of small amounts of materials added to the large mass of starting ingredients, and we have therefore become emboldened to predict how the deliberate addition of specific chemical compositions may influence the final end product performance.

Swanson and others have pointed out certain factors that can be used to rationally explain the effect of various papermaking materials. These are principally:

1. Pulp fibers have a multitude of hydroxyl groups potentially capable of interaction by hydrogen bonding.
2. Hydroxyl groups (on a molecular scale) are strongly polar.
3. Since the attractive forces between molecules decrease with the inverse seventh power of the distance between them, it is essential that elements of the fibers which are to be bonded together must approach one another within a very few Angstrom units if the bonding forces are to be effective.
4. Wet-end additives (beater adhesives) are able to bridge distances between fibers (that have not approached each other closely) and thus establish bonds that would not have otherwise formed.

Table I. Cornstarch Retention at 2% Dosages 50/50 Bleached Sulfite/Groundwood Handsheets
Effect of Treatment Conditions

Type of additive	% Retention (1)	(2)	(3)	(4)	Burst (1)	(2)	(3)	(4)
None—blanks	..	..	..	..	12.2	11.0	10.2	10.5
Dimethylolurea-(DMU) cross-linked pearl starch[a]	43	55	62	53	12.6	9.9	11.5	11.0
Hydroxyethyl ether pearl starch[b]	26	39	48	39	11.7	11.2	12.7	11.9
Carboxyethyl ether pearl starch[c]	20	64	52	57	10.4	11.1	13.0	11.7
Cationic ether pearl starch[d]	40	59	57	56	12.0	11.0	13.0	12.0

[a] U. S. pat. 2,407,071 (1946), Gill, L. O. and McDonald, J. W.
[b] Hydroxyethyl content = 2.0–2.2%.
[c] Na-carboxyethyl content = 2.0%.
[d] Di-ethylamino ethyl ether content = 2.0%.
(1) No additions or pH adjustments, pH = 9.0–9.5.
(2) Adjusted system to pH 5.0–5.5 with alum before adding starches.
(3) Added 1% rosin size, the starches, finally alum to pH 5.0–5.5.
(4) Added 1% rosin size, alum, lastly the starches, pH 5.0–5.5.

Table II. Retention and Strengths with Starch Fractions on Natural Kraft Pulps (730 ml. S.-R.)
2% Rosin Size, pH 6.5–7.0

Starch type	% *Additive*	% *Retention*	*Burst*
0	0	..	42.0
Corn amylose	1	33	43.4
Corn amylopectin	1	?	43.0
DMU pearl	1	27	44.4
Chlorinated	1	6	41.4
Corn amylose	2	31	45.7
Corn amylopectin	2	?	45.9
DMU pearl	2	30	44.7
Chlorinated	2	6	42.3
Miller's work:			
0	0	..	23.7
Potato amylose	2	?	38.0
Potato amylopectin	2	?	45.3
Pregelled Corn	2	?	37.5

Electron photomicrographs by Jayme and Hunger (*3*) present convincing evidence that the elements of separate portions of the wood fiber cell structure may become hydrogen-bonded during sheet formation after normal beating sequences.

The Campbell (*4*) effect serves to show how water, wettability, and high surface tension bring about intimate contact of paper fibers so that hydrogen bonding tendencies can become fiber-to-fiber bonding realities.

The enhancement of fiber-to-fiber bonding by the inclusion in the wet-end system of polysaccharide additives provides us with an opportunity to study what happens when various chemical structures or modifications are present in the fiber-water-air interface as the fiber-to-fiber bonding proceeds.

From a critical analysis of the results gained with various wet-end additives we should expect to eventually accumulate enough information so that we can predict the results of the use of certain specifically modified products.

PROGRESS REPORT ON WET-END ADDITIVES

In September, 1959, we were able to report (*5*) the results of adding variously modified starch-based wet-end additives to laboratory handsheet preparations of paper. Tonight we take this opportunity to make a progress report of what has been done since then. We must keep in mind Swanson's caution in the form of the question, "Why doesn't this work in my own mill?" but perhaps we can catch an idea for our own application from this report.

During the discussion of our last report, a question was raised as to the necessity of having aluminum ions (alum) present to get sorption of a starch wet-end additive. We are now able to report that while the presence of aluminum increases the absolute amount of starch additive retained it is not essential to retention. It was also found that the sequence of addition of starch-based additives in a rosin-sized sheet affected the retention of some but not all products.

The anionic carboxyethyl ether starch is rather poorly retained without aluminum ion, but becomes the best retained with aluminum.

The cationic diethylaminoethyl ether starch does not differ significantly in retention in this instance from the anionic starch except in the "no treatment" condition.

There has been a recent report (*6*) that amylopectin, as a wet-end additive, gave higher strengths than amylose or whole starch. This report puzzles us as it does not accord with our own laboratory experience. It is, however, in accord with the results reported by Pearl (*7*).

Table III. Retention and Strengths with Various Starches on Kraft or Bleached Sulfite Handsheets

pH 6.0–6.5, Dosage Level 2% (40 lb. per Ton) 1% Rosin

Starch type	% Retention		Burst		Tensile	
	Kraft	Sulfite	Kraft	Sulfite	Kraft	Sulfite
None	..	..	47.4	32.0	15.2	10.9
DMU pearl	35	55	45.7	34.2	15.1	11.6
Hydroxyethyl	21	36	50.6	32.1	15.6	11.3
Cationic ether	42	51	51.3	37.0	15.4	12.8
Chlorinated	4	4	46.9	31.5	15.4	10.6

Many investigators have reported major differences in the effectiveness of specific wet-end additives depending upon the chemical treatment during the pulping operation. Karna and Nordman (*8*) found vegetable gum additives more effective on sulfite than on sulfate pulps and more effective on bleached than on unbleached pulps. Conversely, we might speculate that certain types of additives would be more effective on unbleached pulps if a concept of possibilities of hydrogen-bonding of the additives to the lignin structures is encouraged (*9*).

In Table III, we see compared the degree of retention of six different types of starch wet-end additives on natural kraft and bleached sulfite pulps. Here we see several apparent inconsistencies in terms of high strength increases at low or moderate starch retentions on one pulp (kraft), whereas the strengths of bleached sulfite handsheets run reasonably proportionate to the amount of starch retained without reference to structural features.

In a previous study where 2% rosin sizing and an alum pH adjustment to pH 5.0 to 5.5 was used, the hydroxyethyl starch retention was of the same order; but the burst value increased from 28.9 to 31.9. We may thus predict that not only is the strengthening value of any additive dependent upon its molecular structure, but that also the presence or absence and amount of sizing components will affect the results one may achieve.

A somewhat different aspect of the ability of polysaccharide additives to sorb onto cellulosic fibers and to provide strengthening was shown when cotton linters were beaten in the presence of cooked solutions of various starch products. Table IV shows the development of freeness, burst, tensile, and folding resistance as the indicated amounts of starch product was sorbed onto the fibers to show up in the final finished handsheet.

Table IV. Beating Cotton Linters in Presence of 10% Cooked Starch (on Fiber Weight)

Starch	Beating time, hr.	Freeness, mls S.-R.	Starch, % on fibers	Burst	Tensile	Schopper folds
DMU pearl	1	830	1.1	9.9	3.4	5
	2	760	1.8	16.3	5.5	19
	3	515	2.5	17.7	6.7	42
	4	340	3.3	23.5	8.2	79
	5	230	3.5	25.0	9.0	167
	6	180	3.9	24.4	9.3	173
Cationic ether	1	870	2.9	11.1	3.2	7
	2	770	3.5	17.8	5.4	24
	3	410	4.6	25.2	8.0	112
	4	255	4.4	27.8	9.3	241
	5	215	5.4	28.5	9.6	292
	6	160	6.0	26.5	11.3	388
Chlorinated	1	840	0.4	8.6	2.7	3
	2	715	0.4	13.1	4.4	9
	3	560	0.4	15.2	5.6	14
	4	390	0.4	17.2	6.5	29
	5	335	0.4	17.4	6.8	28
	6	210	0.4	17.1	8.4	37
Carboxyethyl ether	1	835	0.1	8.5	2.7	3
	2	745	0.1	12.8	4.5	12
	3	500	0.2	16.5	6.0	23
	4	315	0.2	18.9	7.0	37
	5	225	0.4	20.6	8.4	101
	6	165	0.5	19.3	8.4	61

Sales, trade, and technical literature sources continue to indicate considerable interest in and use of natural gum products such as locust bean or guar as wet-end additives. While chemical modifications of natural gum additives are commercially available, the additional cost probably makes their application to papermaking of doubtful interest.

Various modifications of starches not commercially manufactured until a few years ago are now available for paper mill application with interesting claims made as to their properties and performance. The new starch modifications suggested for industrial application include acetate (*10*), phosphate (*11*), sulfate (*12*), esters, propionamide (*13*), ethers, imino carbamates (*14*), dialdehyde and dicarboxyl starches (*15*).

IMPLICATIONS FOR FUTURE RESEARCH

The rather recent arrival of an atmosphere in which critical evaluation of the effect of molecular shape, size, chemical structure and modification of additives for the papermaking process is encouraged and appreciated promises to bring newer and better products.

Suppliers will look upon their raw materials as chemicals which can be put through controlled reaction procedures rather than purely as commodities to build profits. The introduction of specific groupings or the specific alteration of molecular configuration will be undertaken because we will have learned that such procedures bring improved performance and increased efficiency to the customers we serve.

Borrowing from what we know about other scientific disciplines or analogous fields of chemistry we can look forward to predict what we may one day have to help us in papermaking.

Increased retention or "adhesiveness" must hopefully result from the deliberate introduction of groups which can increase the hydrogen-bonding capacity of wet-end additives.

Molecular configurations or substituents which can increase the "spreading" and "holding" potentials of the products should give increased efficiency. Atomic groups which are known to have specific donor or acceptor values in hydrogen-bonding suggest themselves as the first candidate to be examined.

One might go on at great length with wild ideas of "blue sky" chemistry and perhaps hit upon some ideas which might turn out to be useful. In a more serious manner, we expect that the industry will demand many innovations in wet-end additives and that your suppliers will devote ever larger amounts of research funds to the search to discover more effective wet-end additives with either broad spectrum applications, or conversely, well-defined products with narrow ranges of use and extremely precise and predictable responses.

Our searches will be more fruitful to you in the industry if you will share with us some of your plans for the future by telling us not only what you need for today and tomorrow, but more particularly, your needs for five years from today. We want the challenge of helping you get there sooner with better and more useful products for better papermaking.

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Presented at the meeting of the Ohio Section of TAPPI, held in Middletown, Ohio, Jan. 10, 1961.

Southeastern

The first meeting of Southeastern Section of TAPPI in Atlanta, Ga., was held at the Dinkler Plaza Hotel on Nov. 18–19, 1960. This "first" was also noteworthy with the attendance of R. G. Macdonald of National TAPPI in attendance. Mr. Macdonald reported on some of the latest local section changes.

William Emmett Boyett of Mead, Atlanta, welcomed the membership to Atlanta as host for the evening.

H. T. Robson, program chairman, had a fine group of papers for the evening. The first two were part of the section's annual award contest.

"Self Heating of Paper," was presented by M. B. Cunningham of Sonoco Products Co., Hartsville, S. C. This paper described the circumstances surrounding the spontaneous ignition of rolls en route to a customer and the investigation that followed.

The following conclusions were reached:

1. Very dry rolls* (0 to 3% moisture) are subject to self heating. For rolls in the range 2300 to 2800 lb., the temperature rise continues over a 36-hr. period.
2. Tight winding may accentuate the situation.
3. Some evidence indicates that size may accentuate the problem.
4. Moisture content over 5% will eliminate the problem.
5. Earlier studies show that self-heating due to extractives in the board may occur when the board is heated sufficiently to start the reaction.

The second contest paper was presented by Julius H. Mappus of the West Virginia Pulp and Paper Co., Charleston, S. C. His title was "Fatigue Resistance of Extensible and Conventional Kraft Papers." Mr. Mappus reported on experimental work with the Instron stress-strain tester and the Thwing-Albert impact resistance tester. The particular application was multiwall bag paper.

The usefulness of both instruments was brought to light. The relationship between fatigue failure and applied load was indicated to be dependent on rate of loading. The improved fatigue resistance of extensible paper was pointed out.

The feature speaker of the evening was K. Q. Kellicutt of the Forest Product Laboratory, Madison, Wis. His topic was "How Paperboard Properties Affect Corrugated Container Performance."

The most important physical property of linerboard for predicting performance of finished boxes was shown to be modulus of elasticity. It is an inherent property of the liner resulting from fiber type and manufacturing process.

The moment of inertia on the other hand is related to the component corrugated materials and their arrangement.

The paper showed application of the aforementioned factors to box design and gave experimental data to illustrate.

On Saturday morning, November 19, the TAPPI group visited the Atlanta Wire Works and the Atlanta Steel Co.

M. Benjamin, *Recording Secretary*

* The rolls were made from a furnish of 80% old news and 20% old corrugated boxes.

Self Heating of Paper

M. B. Cunningham

A shipment of paper ignited spontaneously in shipment. The circumstances surrounding the fire are given and the attempts to determine the source are described. No concrete evidence as to the cause of the fire was determined, however, suggestions are given to prevent reoccurance.

Last summer, Sonoco Products Co. had the unfortunate experience of having a shipment of paper ignite spontaneously while en route to the customer. In this presentation, I shall present to you the circumstances surrounding the fire, our attempts to find the source of it, and also what we are doing to prevent recurrence of the conditions which propagated the fire.

The type of paper involved in the shipment was a 20-pt. board made from a mixture of 80% old newspapers and 20% old corrugated boxes. The furnish was pulped in a Shartle Hydrapulper and then through jordan refiners to the cylinder machine. The pulp contained approximately 19 lb. of alum and approximately 8 lb. of dry rosin size per 1000 lb. of stock. The rosin size was dissolved in water and added to the chest. Two tenths per cent or less of a foam breaker solution of $^1/_2$ no. 2 fuel oil and $^1/_2$ commercial foam breaker was added to the stock.

The board was slit into rolls—half of which were approximately 15 in. wide and the other half approximately 18 in. wide, three rolls of each width being produced from each reel. The three 15-in. rolls were packaged into one large roll at the winder by wrapping them with three or four wraps of unslit board. The three 18-in. rolls were unitized in the same manner. All rolls were approximately 60 in. diam. and very tightly wound (see Fig. 1 illustrating the unitized package).

The rolls were shipped in 50-ft. railroad boxcars, approximately 40 tons per car and were loaded solid throughout the length of the car. Eight carloads of board were made and shipped in this manner.

Three days after the paper was made, boxcar no. 1 arrived at the customer's plant and was discovered to be on fire. Board in this car was burned badly as well as the boxcar itself (see Figs. 2, 3, and 4 illustrating fire in boxcar and the damaged paper).

Representatives from Sonoco immediately went to the customer's plant to determine the source of the fire. Rolls of paper from the burned boxcar were examined and the following figures illustrate where the fire started in the rolls of paper (see Figs. 5 and 6).

Our representatives then began to examine the other seven

M. B. Cunningham, Sonoco Products Co., Hartsville, S. C.

Fig. 1. Unitized package

Fig. 2. Fire in boxcar

boxcars for possible fires. A probe thermometer was placed in a roll in car no. 2 and the temperature was found to be 345°F.; this was 7 days after the paper was made. All of the rolls were removed from boxcars 2 and 3 and placed under tarpaulins in the mill yard. Cars 4, 5, 6, 7, and 8 did not appear to have much heat in them so they were left

Fig. 3. Damaged roll

intact. Three days later, or 10 days from the date of manufacture, board in car 4 ignited in the same manner. Board in cars 5, 6, 7, and 8 became warm but never did reach the ignition point.

At this stage of the investigation, it became apparent the first half of the 8-car shipment was giving trouble with over-

Fig. 4. Damaged roll

Fig. 5. Dark spot on center roll of unitized package

heating while the last half was giving little evidence of heating. Our first efforts in locating the cause of the over heating was, of course, to see if the first half of the run was made in any manner different from the last half of the run.

Examination of our Inspection Department's test data, which included air resistance, water saturation, tensile and moisture tests, did not indicate any appreciable difference between the first half of the run and the last half. All available data from the machine and from the beater room were examined and still no difference between the first half of the run and the last half could be found. We have suspicions, however, that the moisture content of the board, as produced, was too low.

Samples of board from the eight boxcars sent to the customer were sent to our laboratory where extensive tests were run in an effort to find some difference between the board which overheated and the board which did not overheat. These tests included alcohol-benzene extractives, water absorption, Riehle, mullen, weight, pointage, and air porosity. None of these tests were significantly different from roll to roll. Of course, the portions of the rolls which had been subjected to high temperatures did give low physical tests, but this was to be expected. Alcohol-benzene extractives, as determined according to TAPPI Standard T6 m-54, were in the range of 0.3 to 0.4%, based on the o.d. board, on all of the samples tested.

After having found no reason why one part of the shipment would overheat and the other part would not, it was decided to make an experimental run in the paper mill duplicating, as nearly as possible, the conditions which existed when the original ill-fated shipment was made.

Two sets of board were made during this experimental

Fig. 6. Close up of dark spot on center roll

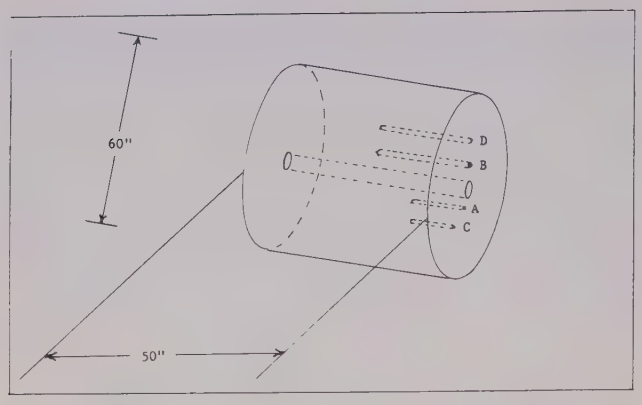


Fig. 7-A. Positions of thermocouples

run. One set contained rosin size, alum, and foam breaker; the other set contained no chemicals. Each set was made approximately 60 in. diam. rolls approximately 50 in. wide, tightly wound, and, intentionally, with low moisture content. Four thermocouple wires were wound into each test roll as the paper was being wound on the rewinder. Thermocouple wires were placed in the test rolls in the following positions:

A—3 in. from the core and 8 in. from the face of the roll
B—3 in. from the core and 24 in. from the face of the roll
C—14 in. from the core and 8 in. from the face of the roll
D—14 in. from the core and 24 in. from the face of the roll

(See Fig. 7A for illustration.)

Temperature readings were made at intervals of 1 to 2 hr. during the next 105 hr., or $4^1/_2$ days. Charts of the temperature readings versus time for the first 87 hr. are shown in Figs. 7 and 8.

Examination of these charts shows that there were some rather erratic changes in temperature in the rolls. In each roll, the temperature of the spots 24 in. from the face of the roll showed a definite temperature rise several hours after the roll had been wound. In each roll, the temperature of the spots 8 in. from the face of the roll showed a gradual decrease with time. A slight net rise in temperature was noted in the unsized roll while a considerable net rise was noted at the corresponding point in the sized roll. The temperature rise was marked by periods of recession and recovery. Comparison of the curves on the charts showed that while some of the variations may be experimental or instrumental errors, many of these appeared to be real and would appear to demand some explanation other than spontaneous combustion.

According to our understanding of spontaneous combustion, this condition arises when an easily oxidized material is so confined that the heat developed is not easily dissipated and when sufficient access to air is provided.

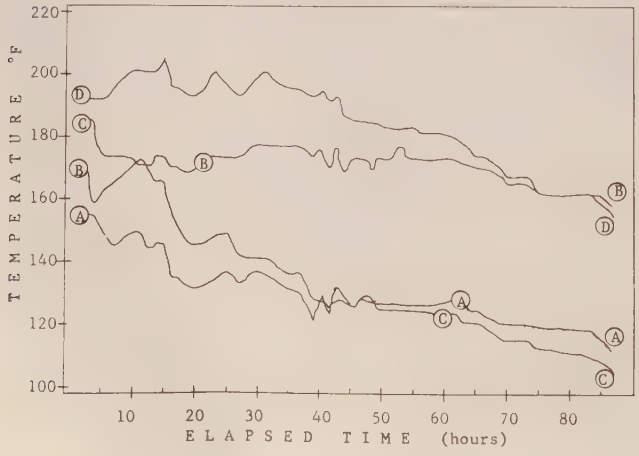


Fig. 7. Temperature versus time (unsized roll)

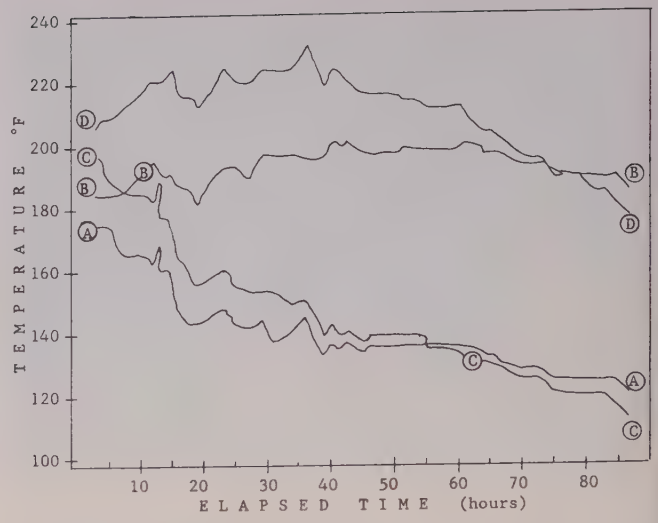


Fig. 8. Temperature versus time (sized roll)

After initiation of the reaction, the temperature rises steadily until the ignition temperature is reached. The foregoing chart of curves strongly suggested that if spontaneous combustion is concerned, then there is a second factor which must be reckoned with in order to explain sudden rises of temperature which were often followed by subsidence.

We do not have (as far as we know) a single case of spontaneous combustion having occurred in our warehouse although thousands of tons of hot and comparatively dry paper must have been stored there from time to time in the past years. We do know that we have had three fires (including the one under discussion) that have occurred in transit or shortly after transit.

Consideration of these facts led one of our chemists to present an hypothesis of strain energy which is stored in the rolls both at the winder and at the rewinder. His reasoning was this: paper, like plastic materials, is stretched by tensile forces. The extent of this stretching is dependent upon the magnitude and the direction of the tensile force, and, of course, the nature and condition of the paper. This strain energy must certainly be stored in every roll and would be accentuated by the tightness of wind. Near the core of the roll the pressure of the overlying plies would be so great that readjustment (relaxation) of forces would not take place until the roll is unwound. The outer portion of the roll would be under light pressure and any movement of plies would not be accompanied by much heat. Somewhere about the central portion of the roll, with respect to the periphery and the core, the coefficient of friction could be expected to just balance the readjusting forces, so that any sustained vibration would promote the readjustment. Hence, development of heat at this point would also coincide with the point of maximum insulation. It would seem, therefore, that all of the pertinent facts fit the theory extremely well. Two other facts seemed to lend further credence to the theory: the sized roll in the experimental run increased in temperature more than the unsized roll indicating the possibility of more friction between plies with resultant heat generation. It was also noted that on several occasions, distinct audible "pops" were heard coming from the rolls, indicating the possibility of ply slippage or readjustment. It should be remembered that the theory was tailored to fit the facts and not the facts to fit the theory.

In order to test the foregoing hypothesis, another experimental run was made in the paper mill. Two sets of board were run as nearly as possible like the board which caught fire. One set was run with approximately 2% moisture and one set with approximately 5% moisture. Both sets contained dry rosin size, alum, and foam breaker.

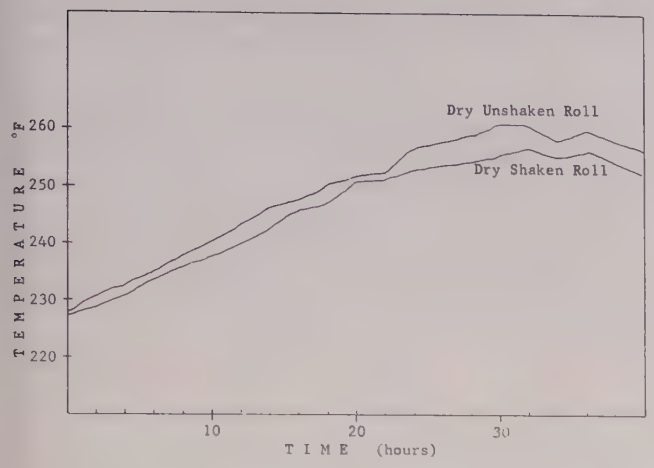


Fig. 9. Temperature versus time (effect of shaking)

Before making this run, our experimental shop built for us a platform shaker which would simulate vibration which a roll would receive in shipment.

Thermocouple wires were placed in the rolls at the rewinder. One of the dry rolls (2% moisture) was placed on the platform shaker, another dry roll and a more moist roll (5% moisture) were placed nearby on the floor. All rolls were covered separately with asbestos felt to minimize heat loss. The thermocouples in all three rolls were wired to the potentiometer for temperature measurements. These thermocouples were placed in comparative positions in each roll at the point of expected highest temperature rise. The platform shaker was started and run intermittently for 3 days. Temperature readings were taken periodically from all three rolls. Figure 9 shows the time versus temperature curves for the two dry rolls.

Examination of the data shows that there was no significant difference in rates of heating between the shaken roll and its companion roll which was not shaken. The roll with higher moisture showed very little heating tendency. All curves in this experiment showed rather smooth and regular patterns, but there were a few points which did suggest small abrupt changes. All in all, it would seem that there can be a rather serious rise in temperature independent of any shaking or vibration.

In our search to find other possible sources of heat, the possibility of heat generation by moisture adsorption has been investigated. By now it is well established that dry paper will pick up moisture from the air and that this will cause a sustained high temperature, or that a cooled dry roll will rise in temperature if suddenly exposed to humid conditions.

A laboratory experiment was conducted to demonstrate the effect of moisture adsorption on temperature rise. A ball of pulp a little larger than a baseball was made and a thermometer well was formed in the ball of pulp. The pulp was then placed in an oven long enough for it to become moisture-free. It was then placed in a desiccator overnight so that it could cool in dry air. A thermometer was placed in the well and the ball of dry pulp was placed in an atmosphere of high humidity. The dry pulp weighed 23.09 g. and the temperature was 26.0°C. (78.8°F.). Table I shows the elapsed time versus temperature rise in the ball of pulp.

Table I. Time versus Temperature Rise—Ball of Pulp

Time, min.	*Temperature* °C.	°F.	*Weight, g.*
0	26.0	78.8	23.09
3	29.0	84.2	. . .
5	32.0	89.6	. . .
7	36.0	96.8	. . .
10	38.0	100.4	. . .
12	40.0	104.0	. . .
15	42.0	107.6	. . .
17	43.0	109.4	. . .
20	43.0	109.4	. . .
25	43.5	110.3	. . .
30	43.0	109.4	. . .
35	42.0	107.6	24.05

After 25 min. the temperature of the ball had risen to 43.5°C. (110.3°F.). During this time, the pulp ball increased in weight to 24.05 g., an increase of 3.9% due to moisture. The experiment gave positive evidence that there is a positive heat of adsorption as dry paper adsorbs moisture from the air. This confirms the fact that a roll of paper at moisture less than equilibrium with the atmosphere can hold its "off the machine" temperature for a long period of time, or even actually increase its temperature, as it adsorbs moisture from the atmosphere.

Self-heating of board due to extractives in the board has been considered. Kenneth N. Smith, in an article entitled: "Self Heating of Wood Fiber," presented at the 1959 Annual TAPPI Meeting, points up the part played by benzene-alcohol extractives in pulp and shows that, under the conditions imposed, self-heating is very much affected by these extractives. This work was done at 325°F. and above. We do not doubt that, once this temperature is reached, the reaction would be self-supporting.

Temperature measurements on several machines in our paper mill have shown some interesting facts.

Table II shows paper moisture, temperature drop between dryer and reel, and average temperature of the paper on the reel for four paper machines.

Table II. Machine Comparison

Machine number	*Paper moisture, %*	*Temperature drop between dryer & reel, °F.*	*Average temperature of paper on reel, °F.*
4	3.6	67	223
5	5.1	127	128
2	9.3	60	128
7	7.0	86	154

These measurements indicate that paper with moisture content below specification (5% minimum) will *cool down* from its drier section temperature at a *slower* rate than will paper with specification moisture of 5 to 8%. Although the *3.6% moisture content* paper from no. 4 paper machine left the drier section at the high temperature of 290°F., it did not cool off nearly as rapidly as the paper from machine no. 5 (at 5.1% moisture) and no. 7 (at 7.0% moisture) which left their respective drier sections at temperatures of 255°F. and 238°F. The paper from no. 2 paper machine was slower to cool than that from no. 4 machine, but it left the drier section at the low temperature of 188°F.

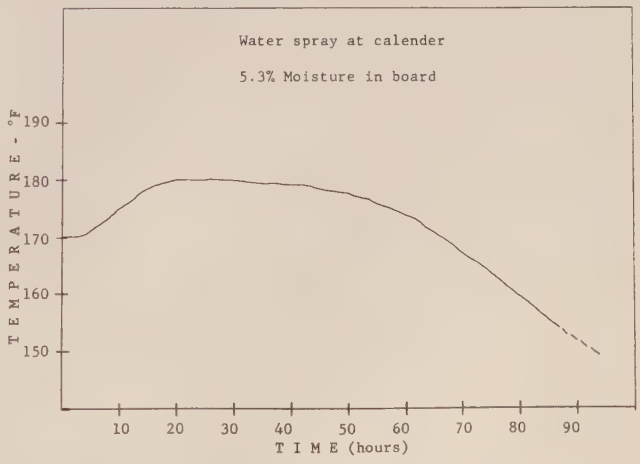


Fig. 10. Temperature versus time

It is known that our paper machine no. 4, which was the one on which the ill-fated shipment of "hot" board was made, has a tendency to produce board with wet spots. In order to eliminate the wet spots, it is probable that portions of the board were dried excessively. It was our feeling that excessive drying was a contributing cause of the hot paper.

With this fact in mind, we purchased for our no. 4 machine a water spray system to apply water to the board just prior to the calender stack. On a subsequent run of board for the same customer who received the ill-fated shipment, we dried the board on the machine to remove all wet spots, then re-wet with the water spray system to an average moisture of 5.3%. Thermocouples were placed in a test roll and temperature measurements were taken over a 4-day period. Figure 10 shows the temperature rise on the board.

It can be seen that only a slight rise in temperature occurred. We attribute this to the fact that there was sufficient moisture in the paper to prevent overheating. All subsequent shipments of board of this type have been made with adequate moisture content and we have had no more instances of "hot" paper occurring.

One of our chemists raised this question about critical mass: In atomic physics, we know that a certain critical mass must be attained before the multiplication factor reaches a value 1.0. At this value, and above, the reaction is self sustaining. If an analogy exists in the field of chemical reactions we can postulate that trouble of this sort would only develop where paper conditions were encountered, namely:

1. Dry paper.
2. Tightly wound rolls.
3. A fairly high initial temperature.
4. A "cross section" or mass of such size that any generated heat (from any cause) would accumulate faster than it could be dissipated.

In conclusion, I would like to point out that we do not have any concrete evidence as to exactly what started the fire. This study has shown us the following facts, however:

1. Very dry rolls (0 to 3% moisture) are subject to self-heating. For large rolls such as those we examined (2300 to 2800 lb.), the rise in temperature continues over a 36-hr. period.
2. We believe that the condition may be accentuated by tight winding. There is no proof of this factor at this time.
3. The effect of vibration of the roll may or may not play some part in accelerating the heating.
4. There is some evidence that sizing the board may accentuate the heating problem.
5. It has been shown that a moisture content of 5% or above will prevent overheating.
6. It has been previously shown by other persons that self-heating due to extractives in the board can occur when the board is heated sufficiently to start the reaction.

While we do not have all of the answers to self-heating of paperboard, I hope this has been of some interest to you. I would be most grateful for any comments any of you might have concerning this subject. I would like to express my appreciation to those of our laboratory staff and to the paper mill staff for their work and support. Many of the ideas contained in this paper originated with them.

Since this paper was written, I have heard of other instances of self-heating of paper. In one instance, kraft board was dried down to 2% moisture (at the customer's request) and this dry roll charred badly due to self-heating. In another instance, stacks of hardboard which had been stacked hot and dry ignited spontaneously. In both of these instances, it was found that the self-heating could be overcome by maintaining sufficient moisture in the board and by cooling the board before stacking or rolling.

Presented at the meeting of the Southeastern Section, TAPPI, held in Atlanta, Ga., Nov. 18, 1960.

Fatigue Resistance of Extensible and Conventional Kraft Papers

Julius H. Mappus

Fatigue failures were effected in extensible and conventional kraft papers by subjecting the papers to repeated tensile work loads each less than the virgin work capacity of the strip. This presentation covers: (1) the use of the Instron stress-strain tester and the Thwing-Albert impact resistance tester (modified Elmendorff tear tester) in performing fatigue tests; (2) the fatigue resistance of extensible and conventional kraft papers; (3) the application of fatigue test data on paper to sack drop test performance.

The drop test is generally used to evaluate multiwall sacks for expected performance. If the sack does not break on the first drop, and if the failure is not one of poor construction, the test can be pictured as a fatigue type test, i.e., submitting the paper to repeated loads each less than ultimate strength until failure occurs. Although tests have been devised to measure the fatigue characteristics of paper, multiwall sack paper is usually evaluated by ultimate tensile, stretch, and toughness (tensile energy absorption) at slow rates of loading.

By virtue of superior toughness, the new extensible papers have proved to give better drop test performance and would be expected to have superior fatigue resistance. However, there are little or no data available on this property of extensible papers. This study was initiated to:

1. Explore fatigue testing of sack paper on the Instron stress-strain tester and the Thwing-Albert impact resistance tester (modified Elmendorf tear tester).
2. Compare the fatigue resistance of extensible and conventional kraft papers.
3. Apply the fatigue resistance of paper to drop test performance.

PROCEDURE

In that the drop test applies a work load to the sack in equal increments—constant height flat drop or constant height butt drop—it was reasoned that the Instron stress-strain tester (with automatic integrator) and the Thwing-Albert impact resistance tester (modified Elmendorf tear tester) could also be used in the same manner to apply work loads in equal increments to strips of paper. Using the Instron would require loading the strip to a constant integrator reading less than virgin toughness; using the IRT would require cocking the segment to an angle less than that required to break. A few preliminary trials showed that both instruments could be used to measure fatigue resistance of paper. Failures could be produced in tensile strips by repeated work loads each of magnitude less than the estimated virgin toughness of the strip.

Square foot samples from production were the basic source of test material for this study. All samples in a weight and grade category were from the same lot. Nine strips 1 in. wide were cut from each square foot sample. In one series of tests, one strip from each ten sheets was used as a control strip for the lot. In later tests, the nine strips were numbered in sequence across the sheet and even-numbered strips were used as control; odd-numbered strips were used as test specimens. In such a series, the controls and test specimens were alternate strips from a single square foot sample. A summary of the weights, grades, and number of tests is tabulated below. All samples were kraft paper manufactured by the Charleston paper mill of the West Virginia Pulp and Paper Co. Samples were conditioned at 50% R. H. and 73°F. 48 hr. prior to testing. Just prior to test-

Julius H. Mappus, Development Supervisor Extensible Paper, West Virginia Pulp and Paper Co., Kraft Div., Charleston, S. C.

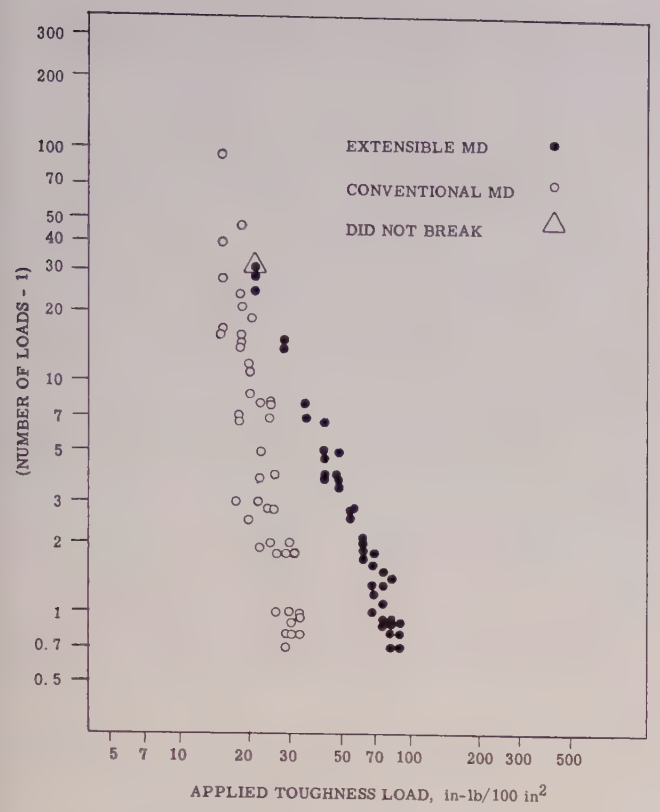


Fig. 1. Fatigue resistance of 50-lb. kraft papers in machine direction under Instron stress-strain load

ing, strips were laid on the table alongside the test instrument for 2 hr. for additional exposure.

Summary of Tests

Weight and grade	*Instron test* *Test strips*	*Con-trols*	*Impact test* *Test strips*	*Con-trols*
50-lb. Extensible paper, MD	49	10	45	36
50-lb. Conventional paper, MD	50	18	40	32
50-lb. Extensible paper, CD	30	24	45	36
50-lb. Conventional paper, CD	30	24	30	24
40-lb. Extensible paper, MD	15	12	..	..
40-lb. Conventional paper, MD	15	12	..	..
60-lb. Extensible paper, MD	15	12	..	..
60-lb. Conventional paper, MD	15	12	..	..

In making the tests, the virgin strengths—tensile, stretch, toughness or impact resistance of the control strips—were first determined. Next the test specimens were immediately tested at applied loads of less than the average virgin toughness or impact resistance. In using the Instron, all strips of a set of nine or ten were clamped in the upper jaw imultaneously. The initial strip length was 5 in.; the width 1 in. The strain rate was 0.5 in. per min. for all samples. An unloading rate of 12 in. per min. was used. In using the Instron in this manner, it was necessary to observe the integrator and unload the strip at the desired reading by pushing the return switch. For extensible papers, the spread between the maximum and minimum applied load on a single strip was about 1 in.-lb. per 100 sq. in. For conventional papers the spread was about 2 in.-lb. per 100 sq. in. due to the more rapid work loading rate at the equal strain loading rate.

In using the impact tester, the strips were clamped individually. The initial strip length was $4^3/_8$ in.; the width 1 in. In applying the impact load, the segment was held at the desired angle* and steadied by the release plate. The segment was released and the plate depressed simultaneously. It is estimated that the segment could be held within $^1/_2°$ of the desired angle.

The applied toughness load could be easily calculated as a percentage of the average virgin toughness. The applied impact load was calculated from the angular displacement of the pointer. The method of calculation is given in Appendix A.

Average stress-strain characteristics of the paper used in this study are presented in Appendix B.

DATA

Preliminary plotting of the data showed that, as was expected, the number of loads increased rapidly as the applied load was decreased. The best straight line was obtained by plotting log (no. of loads—1) versus log (applied load). This type of plot is used in presenting the data.

Typical data are plotted in Figs. 1 and 2 with "Number of Loads—1" as the ordinate and the "Applied Load" as the abscissa on logarithmic graph paper. For comparison, the corresponding sheet direction and method of loading (Instron or impact) were plotted in the same graph for both 50-lb. conventional and extensible paper.

It may be noted that fractional loads are plotted. The work sustained in the final load was measured and is included in the data as a fraction of the load sustained. A "No. of Loads" of 4.8 means that the strip required $0.8 \times 50 = 40$ in-lb. per 100 sq. in. to break on the fifth loading after four loads of 50 toughness units. The total applied energy would be $4.8 \times 50 = 240$ in.-lb. per 100 sq. in.

Figure 3 shows all curves for comparison of directional fatigue resistance and method of loading.

In Fig. 4, the "Number of Loads−1" is plotted versus the "Applied - Load - as - a- percentage - of - the virgin-toughness" to show the general nature of the relationship for the several weights.

DISCUSSION OF DATA

The Use of the Instron and Impact Testers for Fatigue Testing

It may be assumed that both the Instron stress-strain

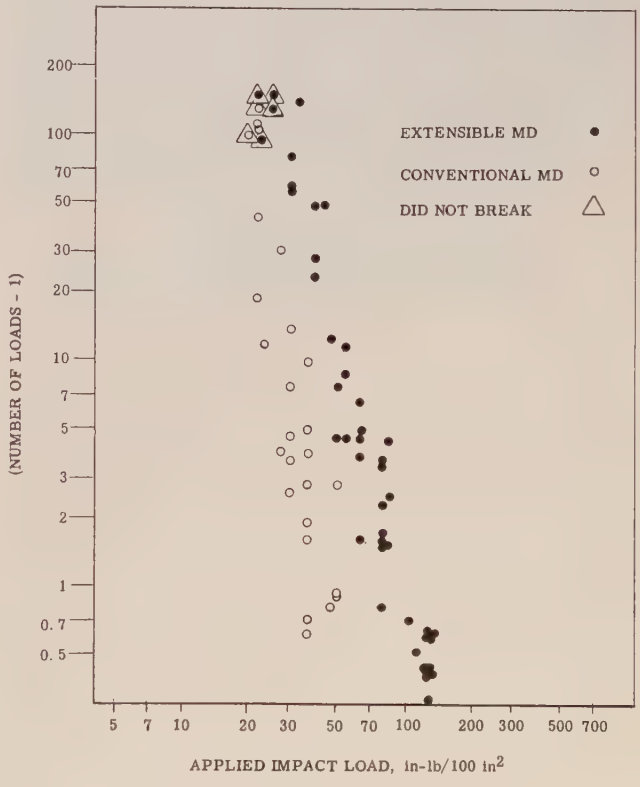


Fig. 2. Fatigue resistance of 50-lb. kraft papers in machine direction under impact load

* The segment was marked with a white pencil at 2° intervals.

tester and the Thwing-Albert inpact tester are capable of testing paper for fatigue characteristics. Failure of the test strip is accomplished by repeated loads each less than the virgin work-absorbing capabilities.

No basic difficulty was encountered in using the two instruments for fatigue tests. The Instron strain rate was set slow enough to permit a reasonable precision in stopping the strain at the desired load. The slow rate of loading and taking up "slack" made the test time consuming. The recording chart made possible the study of stress-strain characteristics of the sheet until failure. This technique could be greatly simplified and higher strain rates could be used if the instrument could be made to reverse at a preset integrator reading.

The Thwing-Albert impact resistance tester offered an advantage of speed without the refinements of the Instron tester. Manipulation of the segment required no undue skills. Angles were marked on the segment, the segment was held to the desired angle, and then caught on the rebound from the impact.

This test is restricted to a fixed velocity at a specific angular setting. (In fact, the impact velocity is different for each angle; however, this was not evident as a factor in the data). The applied energy can be changed by the addition of a weight to the segment. In addition to the fatigue resistance, the maximum extension under load could be estimated from the pointer position after impact; the nonrecoverable stretch, from the slack in the strip (from zero setting and segment positioned to take slack out of strip).

Fatigue Resistance Characteristics of Paper

The plots of Figs. 1 and 2 take the form of typical fatigue curves. In such relationships, the total energy absorbed under the repeated loads is greater than the virgin strength of the material. For example, interpolating from Fig. 1, the data show:

	Applied load	*No. of loads*	*Total applied load*	*Av. virgin toughness*
50-lb. Extensible MD	48	5	240	138.9
50-lb. Conventional MD	24	5	120	36.7

It is evident from above that under tension loads less than breaking loads, paper exhibits nonrecoverable and recoverable work absorbing characteristics.

The line obtained by plotting log (no. of loads—1) versus log (applied load) indicates the relationship is of the form:

$$\text{Log } (N - 1) = \log a - b \log (\text{applied load})$$

or

$$\text{No. of loads} = 1 + a\,(\text{applied load})^{-b}$$

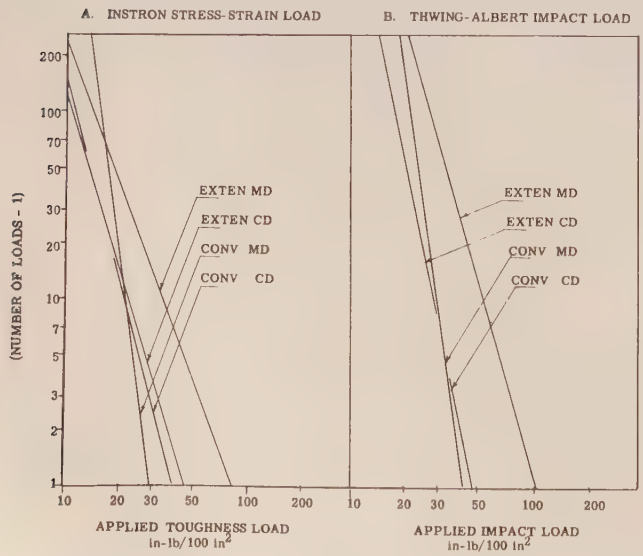


Fig. 3. Fatigue resistance of 50-lb. kraft papers

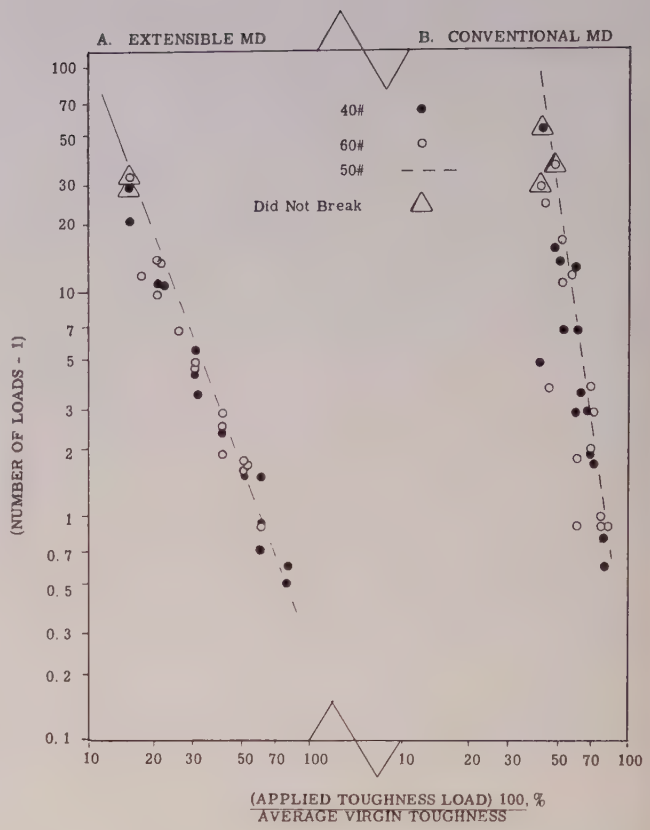


Fig. 4. Fatigue resistance in machine direction of 40, 50, and 60-lb. kraft papers under Instron stress-strain load. Load expressed as per cent of virgin toughness

From the relationship, it is obvious that the number of loads sustained is inversely dependent on the applied load. The slope of the curve, b, relates to the elastic properties of the paper and shape of the stress-strain curve, that is, the recoverable work properties. Different slopes, as shown in Fig. 3, were obtained for MD extensible paper and MD conventional paper; CD slopes are similar to each other but CD slopes are different from MD slopes. Differences in shapes of stress-strain curves of these categories are well established.

The differences in slopes for the different grades and machine orientation indicate that better results would be obtained from a fatigue test at sufficient levels to generate the slope of the curve rather than a single level. In comparing sacks of widely different papers, it seems advisable also to use at least two different drop height levels to better characterize the drop resistance of the sacks.

Data on 40 and 60-lb. weights give curves that generally parallel those of the 50-lb. weights in MD tests. As plotted in Fig. 4, the distinction between weights is very slight when the applied load is expressed as a percentage of the virgin toughness. Thus, while the slope of the curve (b in the equation) may be related to the stress-strain properties, the intercept (a in the equation) appears to be a function of virgin toughness for a specific shaped curve. In other words, the recoverable and nonrecoverable portions of applied energy load possibly follow certain patterns that can be generally predicted from the shape and area of the stress-strain curve.

Fatigue Resistance Extensible Paper versus Conventional Paper

The fatigue plots clearly demonstrate the superiority of this extensible paper over conventional kraft in machine direction This has been borne out by better performance of extensible paper sacks in drop tests and was expected from the superior toughness of extensible paper in tensile and impact tests. However, heretofore, no comparison of the fatigue resistance of these papers per se has been made.

On the other hand, in cross direction, extensible paper seems to be only slightly more resistant under stress-strain loads. This similarity of fatigue resistances in cross direction would be expected because of the similarity of the shapes of the stress-strain curves, virgin toughnesses, and impact resistance in cross direction.

Fatigue Resistance of Paper as Applied to Drop Tests of Multiwall Sacks

The above results offer some interesting speculation as to the performance of such papers in multiwall sack drop tests. The drop test has been characterized by a notoriously high variation in results. These wide variations seem to be characteristic of the fatigue resistance of paper as indicated by the spread of the plotted data. While some of the spread is due to variations in virgin toughnesses, it is felt that strips of paper also exhibit variations in their recoverable work properties. However, the steep slope of the curves show that small differences in the applied load or small differences in the virgin toughness or means a 100% change in performance.

The steep slopes also indicate that the difference between good sack performance and poor performance could be a very slight difference in sack strength. Or a large improvement in sack performance might be effected by a slight improvement in paper toughness.

CONCLUSIONS

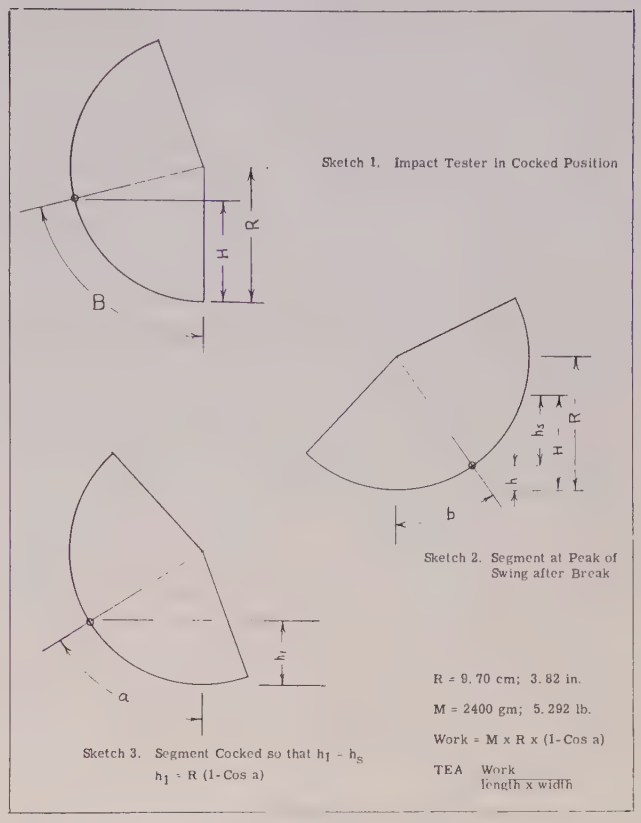
1. Both the Thwing-Albert impact tester (modified Elmendorf tear tester) and the Instron stress-strain tester offer means of measuring the fatigue resistance of paper. The former is more rapid; the latter offers means of studying the stress-strain characteristics of paper under fatigue tests.
2. The fatigue resistance of paper is dependent on the initial toughness of the paper, the applied energy per load and the stress-strain characteristics of the paper.
3. The relationship of fatigue failure to applied load for extensible papers is dependent on the rate of loading: the faster the rate of loading, the greater the number of loads sustained before failure.
4. Extensible paper is considerably more resistant to fatigue failure than regular kraft in machine direction; equal or slightly more resistant in cross direction.
5. The MD fatigue resistance of extensible paper is greater than CD resistance following generally the toughness relationship. The MD and CD fatigue resistances of conventional papers are more nearly equal.
6. The relationship between fatigue failures and the applied load is such that small changes in the applied load (or small changes in the toughness of the sheets at a given applied load) greatly affects the fatigue resistance, i. e., a 30% change in toughness (either applied or original in sample) results in 100% change in fatigue resistance. By inference large differences in drop tests may result from small differences in bag paper strengths.

SUMMARY

This study has been of an exploratory nature into the use of available tensile work measuring equipment for measuring work fatigue of kraft papers. The versatility of the Instron stress-strain tester makes it a very useful tool in studying fatigue properties. The simplicity of the Thwing Albert impact resistance tester makes it useful in measuring the fatigue.

The relationships found here of fatigue resistance to stress-strain properties of paper offer means of better understanding the performance of multiwall sacks in drop tests. It is believed that further study of fatigue resistance of paper will enable the establishment of the long sought relationship of paper property to sack performance.

Presented at the meeting of the Southeastern Section of TAPPI, held in Atlanta, Ga., Nov. 18, 1960.


R
H
B
Sketch 1. Impact Tester in Cocked Position
h
b
Sketch 2. Segment at Peak of Swing after Break
a
Sketch 3. Segment Cocked so that $h_1 = h_s$
$h_1 = R (1 - \text{Cos } a)$
R = 9.70 cm; 3.82 in.
M = 2400 gm; 5.292 lb.
Work = M x R x (1-Cos a)
TEA Work / length x width

Appendix A. Calculation of impact energy for Thwing Albert impact resistance tester (modified Elmendorf tear tester)

Appendix B. Average Stress-Strain Characteristics of Control Strips

	Tensile lb. per in.	*Stretch, %*	*Toughness, in.-lb./100 sq. in.*	*Impact resistance, in.-lb./100 sq. in.*
50-lb. Extensible paper MD	21.1	9.8	139	150
50-lb. Extensible paper CD	18.6	5.4	78	80
50-lb. Conventional paper MD	34.9	1.8	38	66
50-lb. Conventional paper CD	19.3	4.5	63	80
40-lb. Extensible paper MD	18.8	8.9	107	..
40-lb. Conventional paper MD	28.4	1.6	27	..
60-lb. Extensible paper MD	27.1	9.7	160	..
60-lb. Conventional paper MD	41.6	1.6	41	..

How Paperboard Properties Affect Corrugated Container Performance

K. Q. Kellicutt

Design criteria based on the physical properties of the component paperboards have been developed for predicting the performance of corrugated fiberboard shipping containers under a variety of handling and storage conditions (*1*, *2*). Most important of these physical properties is the modulus of elasticity of the paperboard composing the structure. This is shown to be an inherent property that results from the kind of fiber and the manufacturing techniques and processes employed in making the paperboard. The moment of inertia, however, is a property of the built-up corrugated structural material and varies with the dimensions and arrangement of the component paperboards. Both properties are influenced by the kind, thickness, and weight of the liners and corrugating medium; the size and number of corrugations; the adhesive bond; and the

K. Q. Kellicutt, Engineer, Forest Products Laboratory, maintained at Madsion, Wis., in cooperation with the University of Wisconsin, Forest Service, U. S. Department of Agriculture.

quality of fabrication, which are the subjects of this paper. These properties can be utilized, therefore, to establish design criteria for corrugated containers.

A CORRUGATED box can be no better than the three component paperboard sheets from which it is made. If the box is properly designed and properly manufactured, however, much of the inherent stregnth of the components comprising it can be utilized and a high degree of efficiency attained. The design may be divided into two main parts—part 1 pertaining to the physical properties of the paperboard, and part 2 to the manufacturing details involved in fabricating the paperboards into corrugated board and the subsequent operations necessary in forming the finished box.

Ideally, the box manufacturer would specify precisely the paperboard properties he deemed essential for specific end uses, and the paperboard manufacturer would build into the liner stock and corrugating medium those required properties. With these custom tailored sheets, the box manufacturer would fabricate the boxes. Such an arrangement is not, however, economically feasible. Therefore, the next best scheme, that of the paperboard manufacturer standardizing on several grades of liner stock and corrugating medium, will probably continue. Improvement of the end product, the finished corrugated box, then needs to be accomplished by other means. This can be achieved through the use of meaningful design criteria for corrugated fiberboard in shipping containers, and the development of better testing techniques with which to evaluate the component paperboards as well as the shipping container.

PHYSICAL PROPERTIES

A number of physical properties of paperboard and corrugated boxboard have a direct bearing on container design. This discussion, however, is confined to the modulus of elasticity of the paperboard and the moment of inertia of the built-up corrugated board.

Modulus of Elasticity

The modulus of elasticity is an inherent property of paperboard. It varies according to kind of fiber used and the manufacturing techniques and processes employed in making the paperboard. Modulus of elasticity is an especially important property at present because users of corrugated containers are continually striving to obtain stiffer and stronger boxes that will withstand the greater stacking loads that are now being imposed on them. Modulus of elasticity (commonly represented by the symbol E) is a measure of stiffness.

When corrugated board is subjected to bending loads, either as a beam or a column, the resistance to buckling increases in direct ratio with modulus of elasticity. Hence, the higher the E of the components, the stiffer the board; and in turn, the more rigid is the box and the greater its resistance to crushing forces. This may be seen in respect to a column by examining the Euler column formula in the form

$$P = \frac{4\pi^2 EI}{L^2}$$

in which P is the load, 4 is a factor for fixed ends, E is the modulus of elasticity for material of the column, L the length of the column in inches, and I the moment of inertia. For any given column length and moment of inertia, the load required to cause buckling will vary directly with E. If E is doubled, the load required to cause buckling will be twice as great.

The same relationship may be shown by use of a conventional beam formula in the following form:

$$EI = \frac{PL^3}{48\Delta}$$

in which Δ is the deflection of the beam at the center, L is the span between supports, P is the applied load, E is the modulus of elasticity, and I is the moment of inertia.

It may be seen from the formula that as the modulus of elasticity E is increased, a greater load P is required to attain a specific amount of deflection Δ of the beam, provided the span L remains constant.

Since the influence of modulus of elasticity on the stiffness of a corrugated board is so demonstrably apparent, the question is immediately raised, "What can be done about it?" There are several means of increasing the modulus of elasticity of paperboard.

Fahey and Setterholm demonstrated in a study of sweetgum sulfate and neutral sulfite semichemical pulps for linerboard (*3*) that the modulus of elasticity for the cross-machine direction increased as the percentage of sweetgum was increased in their blends of softwood and hardwood pulps. They also demonstrated that, with the higher E values resulting from greater proportions of hardwood pulp in their blends, the bending stiffness also was increased in corrugated boards with liners made from these blends. The increases in board stiffness closely paralleled the increases in the modulus of elasticity.

The density of paperboards is closely related to the modulus of elasticity; as density increases, so does the E. Density of paperboard may be increased by applying greater sheet pressure at the wet press section of the paper machine.

Chemical additives have been found to increase the modulus of elasticity of paperboards, which in turn increases the bending stiffness of corrugated boards made of the treated sheets.

In their work, "Effect of Resin Content of Paper Overlays on the Strength and Stiffness of Overlaid Veneer," Erickson, Ely, and Fahey (*4*) reported:

"The strength and stiffness properties of overlay paper can be significantly enhanced by small amounts of resin impregnation. The most significant improvement is obtained from a resin content of 5%, notably for paper in the wet condition. Both the tensile properties of overlay paper and the flexural properties of paper overlaid on veneer continue to improve with increasing resin content up to about 15% impregnation. Impregnation beyond 15% resin content

Table I. Modulus of Elasticity Values for Five Different Paperboards

Kind of paperboard	*Weight of paperboard, lb. per 1000 sq. ft.*	*Thickness of paperboard, in.*	*Machine direction*	*Stress at maximum load, p.s.i.*	*Stress at proportional limit, p.s.i.*	*Modulus of elasticity, p.s.i.*
Semichemical (corrugating)	25.90	0.0092	With	4527	1720	631,083
			Across	1845	705	214,183
Semichemical (corrugating)	36.03	0.0127	With	3596	1427	483,083
			Across	1850	637	196,967
Fourdrinier kraft (liner)	42.50	0.0167	With	3728	828	609,862
			Across	2484	468	325,950
Fourdrinier kraft (liner)	43.1	0.0128	With	7069	2476	915,141
			Across	3136	931	375,667
Fourdrinier kraft (liner)	70.20	0.0224	With	3610	756	534,281
			Across	2827	408	314,144

appears to be unwarranted so far as further significant improvement of strength properties is concerned."

This work involved northern pine kraft paper made in two thicknesses—0.009 and 0.014 in. These papers were impregnated with a water-soluble phenolic resin to approximate resin contents ranging from 5 to 25%. This refers to the difference in weight of untreated paper and treated paper after cure of the resin, expressed as a percentage of the weight of the resin-cured paper.

Due to its cost, which may be as much as 35¢ a lb., phenolic resin is not likely to be used extensively for the purpose of adding stiffness to paperboard.

Increasing basis weight is not necessarily a means of attaining a higher modulus of elasticity. In fact, in some instances the reverse may result. For example, in the evaluation of two grades of corrugating medium made from the same furnish, but one weighing about 10 lb. per 1000 sq. ft. more than the other, substantially lower values of E were found for the heavier medium. The same was found to be true for the stress at proportional limit and stress at maximum load, both values being higher for the 26-lb. corrugating medium. As these two mediums were similar in density, the difference in E is attributable primarily to sheet formation, the lighter being of higher quality.

A similar comparison may be made with three fourdrinier kraft liners. Two of them weighed nominally 42 lb., the other 69 lb. per 1000 sq. ft. One 42-lb. liner had a much higher modulus of elasticity than the other two, while its actual weight was only 0.6 of a pound more than that of the other 42-lb. sheet and 27 lb. less than the 69-lb. liner. The primary reason for the higher modulus of elasticity of the one 42-lb. liner was its much higher density. The values for the five paperboards are included in Table I.

Of the methods discussed for increasing the modulus of elasticity, the most feasible methods currently being considered are to increase density by making paper machine adjustments and by blending softwood and hardwood pulps.

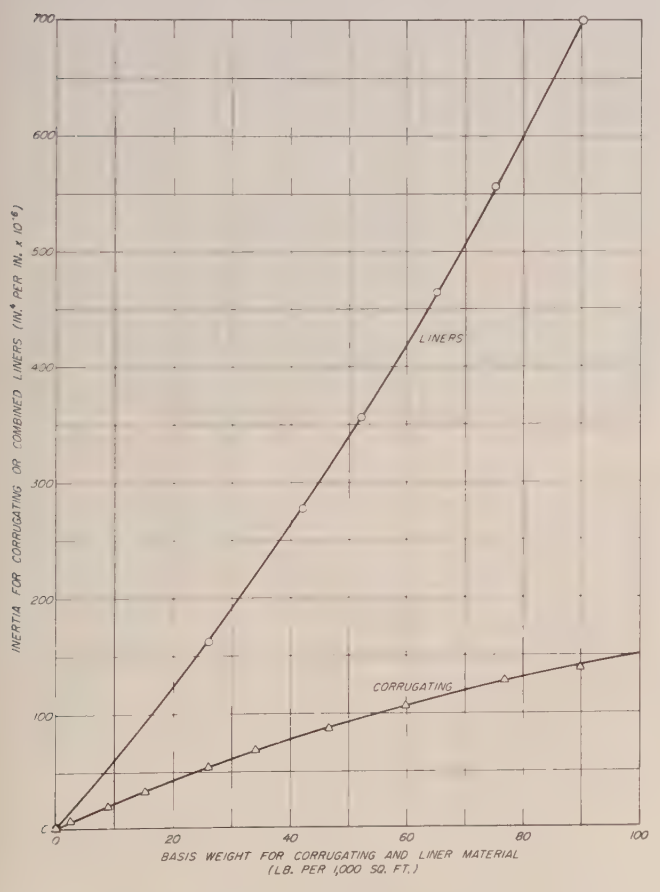


Fig. 1. Relationship of moment of inertia values for various weights of liners to the moment of inertia for corrugating medium in a variety of weights

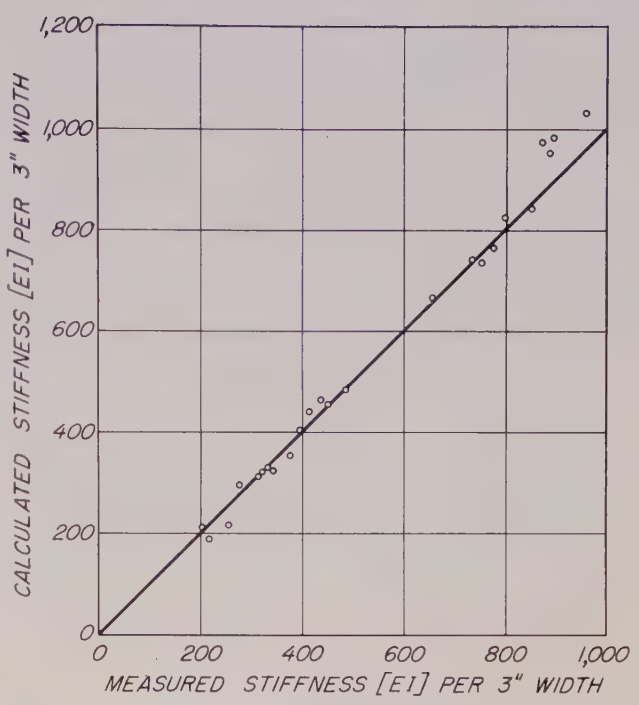


Fig. 2. Calculated stiffness factors EI for 24 experimental corrugated boards compared to the actual values determined from beam bending tests

Moment of Inertia

Corrugated board is not unlike certain other structural materials, such as the sandwich construction consisting of two relatively thin facings bonded to a core. Like the thin facings in sandwich construction, the liners are the principal load-carrying components of the corrugated board. The core of a sandwich, like the corrugated section of fiberboard, is usually a lighter weight material that has low inherent stiffness but, when rigidly bonded to the liners, imparts stiffness and bending strength to the construction.

The corrugating medium, however, contributes appreciably less than the liners to the total moment of inertia of the built-up board. There are three principal reasons for this. First, there is only one corrugating medium in a double-faced, single-wall board as compared to two liners. Secondly, the corrugating medium is generally lighter in weight and thinner than the liner material. Third, and perhaps most important, is the fact that the material in the corrugating medium is disposed more closely to the neutral axis of the board than the liners.

The contribution of the liners and corrugating medium to the total moment of inertia is shown in Fig. 1, a plot of some calculated values (*5*) for an A-flute board with liners spaced 0.180 in. apart. It is interesting to note the contribution made by the liners as compared to that portion added by the corrugating medium for the weights of paperboards generally used. For example, consider a 26-lb. corrugating medium in conjunction with 42-lb. liners. The liners contribute about $5^1/_2$ times as much to the total moment of inertia as the corrugating medium. If you matched a 36-lb. medium with 69-lb. liners, which is fairly common, the liners would contribute about seven times as much as the corrugating medium. The proportions are even more exaggerated when 90-lb. liners are matched with 36-lb. corrugating medium. In this combination the liners contribute 10 times as much as the corrugating medium to the total moment of inertia.

The significance of the relationship of the liners to corrugating medium, in respect to the total moment of inertia of the built-up board, is the fact that the bending stiffness

of corrugated board can be increased appreciably more efficiently by adding weight to the liners rather than to the corrugating medium.

Stiffness Factor

From the moment of inertia for a specific board and the modulus of elasticity values for the materials used in it, the stiffness of the board may be calculated. The calculation consists of the moment of inertia times the modulus of elasticity of the material and has been designated as the stiffness factor *EI*. It is apparent that a change in either, or both, the *E* and the *I* of a board affects its stiffness. This can best be demonstrated by considering several familiar facts.

Assume that three corrugated boards are fabricated from identical paperboards under similar conditions and differ only in that one is an A-flute construction, one a C-flute, and one a B-flute. If boxes were made from the three boards in such a size that the A-flute box tested 1570 lb. top to bottom, the corresponding box made from C-flute would test 1450 lb. and the B-flute only about 1280 lb. A small portion of the difference in strength can be attributed to the fact that there is more material in the form of corrugating medium in the A-flute construction than in the C-flute and B-flute. However, this fact can account for only about 8 lb. between the A-flute and C-flute and only about 13.5 lb. between the A-flute and B-flute. The primary reason, therefore, is the difference in thickness between the three boards, which in reality is the difference in the moments of inertia. For example, in bending tests of two experimental boards, one A-flute and the other B-flute, made from the same component paperboards, the stiffness factors *EI* for the two boards were found to be 119.0 and 44.1 lb. per in. of width, respectively, or 2.7 to 1. An A-flute box, therefore, would test appreciably higher in top-to-bottom compression than the B-flute, although not 2.7 times as high.

As these boards were made from the same components, the modulus of elasticity of the material was the same for both boards. Hence, the difference in *EI* is attributable primarily to the difference in the moments of inertia. The *EI* for a C-flute board, made from the same materials, would fit between those two stiffness factors.

The stiffness factor suggests a means of classifying boards made from various combinations of paperboards, as the calculated values correlate well with the stiffness factors determined experimentally. This may be seen in Fig. 2, which is a plot of the calculated *EI* values of 24 experimental A-flute boards against the actual test values. The stiffness factor may be derived by bending or column tests using the formulas previously given. Or knowing the modulus of elasticity of the components of the corrugated material and the moment of inertia, it may be calculated.

In actual practice, when mathematical analysis of this kind is impractical, a simple method may be employed that will at least partially insure the production of the stiffest box material. The height of flute is one of the most effective factors in the moment of inertia. Hence, corrugating medium with the maximum flute height that it is feasible to produce will provide the best box that can be made—assuming, of course, that the other manufacturing processes, such as bonding the components together, slotting and scoring the sheets, and fabricating the body joint, are all kept at a high standard.

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Presented at the meeting of the Southeastern Section of TAPPI held in Atlanta, Ga., Nov. 18, 1900.

Pacific

Another outstanding technical program by Pacific Section TAPPI was presented at Tacoma, Wash., Jan. 17, 1961. The Top of the Ocean was the location and the general theme of the program was "Process and Quality Control Techniques." Moderating the program was Harold Randles, St. Regis Paper Co., Tacoma, Wash. Beginning promptly at 2:30 p.m., eight papers were presented, the session ending at 5:30 p.m. In order of presentation were the following papers:

1. "Fiber Loss Control," by D. B. Loyd, MacMillan, Bloedel and Powell River, Ltd., Alberni Pulp & Paper Div., Port Alberni, B. C.
2. "Measuring the Delamination of Paperboard," by R. R. Marriott, Crown Zellerbach Corp., Port Townsend, Wash.
3. "Automatic Blow Tank Sampler," by J. M. Elder, Weyerhaeuser Co., Pulp & Paperboard Div., Everett, Wash.
4. "Black Cloth Dust Check on Coated Paper," by R. A. Watt, Crown Zellerbach Corp., West Linn, Ore.
5. "Pulp Chlorination Improvements at St. Helens," by A. A. Schlumberger, Hooker Chemical Co., Tacoma, Wash.
6. "The Skid Resistance Tester-An Instrument for Measuring Surface Resistance to Slip on Paper and Paperboard," by A. J. Beauchamp, Crown Zellerbach Corp., Camas, Wash.
7. "Curing of Handsheets by Far Infrared Radiation," by Bayard Carlson, American Marietta Co., Seattle, Wash.
8. "The Function of Quality Control," by J. J. Whyte, St. Regis Paper Co., Tacoma, Wash.

Immediately following the technical session was a social hour at the same location and succeeding this at 6:30 p.m. a special smorgasbord dinner honored the speakers and guests. Featured speaker for the evening was Reno Odlin, president of Puget Sound National Bank of Tacoma whose topic was "The General Economic Condition of the Country." His intimate knowledge of finance and national and international financial structure created much interest.

ROBERT SMYTHE, *Secretary-Treasurer*

Fiber Loss Control

D. B. Loyd

Measuring equipment and the policies of fiber loss control program are discussed in this paper. Keen management interest, operator participation, and reliable data are all a necessary part of good control. Methods of supplying information and results are discussed also.

THIS paper deals with fiber loss control at the Alberni Pulp & Paper Div. of MacMillan, Bloedel and Powell River, Ltd. We feel that this particular approach has been quite successful in substantially reducing fiber losses at this division from the inception of our expanded paper mill operation. It is perhaps significant to note that the most frequent source of high loss is not the regular or routine daily losses that occur in the various departments, but those losses caused by spills, poor operation, washups, shutdowns, mechanical failure, and things of this nature. An important aspect of reducing losses has been that of gaining operator interest in this fiber loss control program.

BASIC REQUIREMENTS

The three most important factors that make our fiber loss control program successful at the Alberni Pulp & Paper Division are:

D. B. LOYD, Alberni Pulp & Paper Div., MacMillan, Bloedel & Powell River, Ltd., Port Alberni, B. C.

1. A keen management interest in maintaining low effluent losses to the Alberni Harbour. This interest, of course, arises from both economy and pollution aspects.
2. Operator participation and interest in fiber loss control.
3. Reliable measurement and recording of results on all mill department losses.

SAMPLING

Before discussing the various mechanics by which the results or losses are recorded and controlled, some discussion on samplers and measurement is desirable at this point. Many types of samplers have been studied and reviewed by the many people in the Alberni Pulp & Paper Division. Based on experience, four types of samplers have been selected as being desirable for various types of effluents. These four types of samplers are as follows:

1. *The DeZurik Proportional Sampler.* This has been found to be very good for general main sewer service where no abrasive materials, lumpy materials, or chlorinated stock is in evidence. We have replaced the plug end of bakelite with nylon and this has proved very successful.

2. *The Burp Sampler.* This sampler is believed to have originated with the E. B. Eddy Co. and has proved to be very useful for sewers below ground level where there is a small lift and where no abrasive materials or solid materials are encountered. This has been installed in a bleach sewer (PVC) and in kraft white water service. Also used to some extent for newsprint seal boxes.

3. *The Gravity Dump Sampler.* This is believed to have originated with Crown Zellerbach and has been called a "Camas" sampler. This has been found to give excellent performance where concentrations are not likely to run over a half a pound per thousand gallons and the sample source is above ground level. It is most important that no restrictions be placed in the small line feeding the dump sampler. This is applied to a weir by installing the pipe level with the weir crest. It can also be used to sample lines under pressure by taking a 1-in. line from the pipe into the headbox. This has proved very successful in determining quantities of white water transferred from the paper mill to the groundwood white water chest.

4. *The Chain Sampler.* This is perhaps the oldest and most commonly used type of sampler with the small volumetric bucket installed on a rotating chain. This has proved very successful where chunky materials or abrasive materials such as sand, lime, mud are encountered.

Each of the above samplers has been tested extensively by hand sampling. The results of the hand sample are compared to a cumulative sample from the sampler itself. These generally show agreement within about 5%. Where samplers are located, measures have been taken to assure good turbulence so that no stratification can occur giving erroneous results.

WEIRS

We have used Parshall flumes on all main sewer outlets. These have double well measurement since these sewers are backed up a portion of each day at high tide. Most departmental sewers are rectangular weirs or in the case of small flows, V-notch weirs are used to ensure greatest accuracy. All level measurements on weirs are recorded on level charts with a low differential unit for maximum accuracy. Once all samplers have proved reliable by hand checking, it is then a fairly straightforward matter to apply these measurements to the fiber loss control program. The Alberni Pulp & Paper Division makes a sheet up daily from information obtained by weir samples or operator-supplied information.

FIBER LOSS CONTROL

A typical day of fiber loss activity would be as follows: At an early morning operating meeting extraordinary fiber loss reports are brought in from all the departments. It is the departmental responsibility to report what has happened in its operation to cause an extraordinary fiber loss. These are generally caused by spills, washups, poor operation from kickouts. These reports are a very necessary part of supplying sufficient and adequate first-hand information to reconcile successfully fiber losses from the mill. If operators do have a high loss on any day and have reported no reason on the fiber loss report, the manager puts the responsibility right back on the operator to account for this high loss. At times, high losses may be considered doubtful due to faulty samplers or for other reasons. It has been emphasized and proved to a great extent that the samplers are normally right. This is very definitely a correct approach to this type of control. Operators are expected to estimate quantity of fiber loss from a table made up on all tanks, chests, showing quantity of stock per foot at any consistency. At this morning meeting, the losses for the previous day are also reviewed on the daily operating reports and any untoward items that may appear on this from the work of the fiber loss technician are discussed.

The object of all these discussions on unusual losses is, of course, to cut down the losses and to endeavor to point out if there is a mechanical situation in the operation that requires attention or just some poor or careless operation which requires rectifying. In order to eliminate these fiber losses, continually repetitive things such as broke beaters overflowing, beater chest being dumped can be rectified by instrumentation, by operator interest, or by different methods of operation. Also used at this morning meeting are the charts pertaining to broke chest levels, white water chest levels, conductivity charts on our various sewers of which samples are available. These have contributed immensely to cutting down unknown salt cake losses from the recovery, kraft mill, and recausticizing operations.

After the morning meeting, information from the charts and extraordinary fiber loss reports is collated with accumulated samples from all mill sewers to give a complete picture of losses in fiber, lime mud and salt cake. This information is circulated on a daily sewer loss report. The paper mill is divided into machines. Each department is broken into numerous categories and a complete summary on the bottom shows the total fiber to the sewer and its value. The reason for the breakdown of the various items in the department is to show where we are getting continual losses that cannot be reduced. These are circulated to all operators to show each how much his department has sewered the previous day, either as fiber, chemical, or lime rock. Remarks on where the losses occur are placed on this just to re-emphasize the necessity of all operators watching for trouble spots.

WEEKLY INFORMATION

In addition to the daily information, a weekly summary is put out showing the departmental losses to further remind operators of the status of their department losses.

From the period of mill startup, weekly meetings were held to review progress on changes to process to reduce fiber, water, or heat losses and it was largely due to these meetings that losses were reduced substantially from a period of high unknown or extraordinary fiber losses to a period of relatively low fiber loss. As a result of these meetings, trays were installed on our news machines to catch shower water and recirculate it with the result that white water losses from our newsprint system were reduced to next to nothing. Through these meetings, repairs were carried out to decker flumes, new sewers and weirs were installed for better control, changes were made to the recausticizing operation. Closer control on evaporator boil-outs and sewer dumps of black liquor resulted. Decker, washer, and saveall drains were turned into stock chests rather than dumped into the sewer. Attending these meetings were members of engineering, mechanical, and operating departments and it

was through a combined effort that these reductions on waste were brought about.

In addition to these review meetings, progress reports were issued by the technical department on surveys carried out in all mill sewers to establish where unknown miscellaneous losses were occurring. It is noteworthy to mention that our recausticizing system was put under much better control and lime rock makeup to the kraft mill was actually halved as a result of the continuing surveys on lime rock losses. Almost all unknown losses have been pinpointed so that our unaccounted fiber loss is indeed a very low figure.

This system of fiber loss control has been possible through wide use of reliable weirs, recorders, and samplers, and by having one man almost solely on fiber loss work. Process engineers have been put on investigations into these departments to help bring all the unknown losses down to low figures.

We feel that it has been a combined effort of management, operators, and technical department to show a realistic picture of losses as they are and the combined effort of these same people to reduce them to a minimum quantity. We feel that a paper mill fiber loss of something less than $1/2\%$ is a noteworthy achievement when you consider that this represents all losses, not just what has been measured.

Presented at the meeting of the Pacific section of TAPPI, held in Tacoma, Wash., Jan. 17, 1961.

Measuring the Delamination of Paperboard

Robert R. Marriott

The manufacture of carton board and subsequent problems in converting and printing indicated the necessity of measuring the delamination of paperboard. A method has been developed as a routine control test which is quick and simple to perform. It deos not require expensive or special equipment other than a ring crush and tensile tester which are standard equipment for most testing laboratories. This method is felt to be reproducible and correlates with customer requirements. The equipment and procedure are described.

Delamination, internal bonding, fiber bonding, and the other terms which indicate separation or splitting of paperboard are characteristics which have been of great interest to us for some time. Delamination, as we call it in our mill, had been limited in its significance until we began to make carton board back in 1955.

Our no. 1 cylinder machine in Port Townsend had been making linerboard since 1928 with little or no difficulties with respect to delamination. In 1955, one of our customers began to have ply separation trouble with our kraft carton pulpboard during the die cutting, scoring, and folding operation. This was something new to us and we had no way to measure this characteristic other than the traditional papermaker's test of flexing the board by hand and peeling back the plies. An experienced man could say it was "good," "bad," or "okay."

About this same time, another customer was having some delamination difficulty in printing our heavyweight liner. Modern high-speed presses and tacky, gloss inks were making greater demands on our product. This meant that we had to make changes in our manufacturing processes, and also find a way to evaluate these changes so that we would know when our product would meet the customer's requirements.

We needed a routine control test that would be simple and that could be made quickly. We checked with our other divisions and with other mills, but were unable to find a satisfactory method. Time was of the essence, so we took a look at our existing equipment and went to work. We came up with what we call our "delamination tester."

This consists of two 1-in. cubes which are bonded to a 1-in. square sample of board. The combined blocks and sample are then adapted to a standard tensile tester and delaminated, thereby obtaining the pounds of force required.

Following is the material and apparatus necessary for this test:

1. Sample cutter.
2. Sharp jackknife.
3. Two $3/32$ by $1/2$-in. metal straps, $4\,1/4$ in. long with hook slots in the ends (wire spring on lower strap).
4. Two steel blocks, 1 in. square and $1/2$ to 1 in. in depth. Blocks should fit smoothly on their 1-in. face and have a groove approximately $3/8$-in. deep in the back. A $1/8$-in. pin should be inserted at right angles to this groove for hooking onto hook slots of straps.
6. One-inch "Scotch" double-coated pressure sensitive tape No. 400.
7. Ring crush tester.
8. Tensile tester.

Following is our procedure:

1. Cut a 1 sq. in. sample of board.
2. Cover the face of each block with pressure sensitive tape.
3. Place test sample between taped blocks and press together by hand.
4. Place combined blocks in crush tester and press under a load of approximately 200 lb.
5. Place one hooked strap in the upper jaw of the tensile tester and engage hook with the pin in one block.
6. Hook the strap with spring to the pin in the lower block, and fasten to lower jaw of tensile tester.
7. Apply force until the sample delaminates and record as pounds per square inch.

This delamination test has helped us to evaluate the internal bond characteristics of our board, and we are now using it as a routine control test. We have found that it gives reproducible results and correlates with customer requirements.

Our carton board specifications and some linerboard specifications now include delamination test values. On some grades each roll is tested and the resulting value is the basis for acceptance or rejection.

In conclusion, this test is not infallible, however, we have found it very satisfactory for the purpose for which it is intended, and that is to take the guess work out of determining the internal bond of our cylinder board.

Presented at the meeting of the Pacific section of TAPPI, held in Tacoma, Wash., Jan. 17, 1961.

Robert R. Marriott, Technical Supervisor, Crown Zellerbach Corp., Port Townsend, Wash.

Blow Tank Sampler

John M. Elder

It was desired to improve cooking control at the Weyerhaeuser Everett kraft mill by shortening the time lag between blowing and sampling the stock. This was done by developing two systems to sample the stock as it is blown into the blow tank. One system is manually operated and consists of a $1\,1/2$-in. pipe inserted into the blow tank turret. When rotated about 45° it discharges stock into a bucket while the cook is blowing. It costs only a few dollars to build and install. The second system is fully automatic and delivers a composited stock sample, ready for screening, at the end of the blow. This system costs between 1 and 2 thousand dollars to build and install.

Obtaining uniform cooking at Weyerhaeuser's Everett kraft mill has always been difficult because of changing chip

John M. Elder, Assistant Technical Director, Everett Kraft Mill, Weyerhaeuser Co., Everett, Wash.

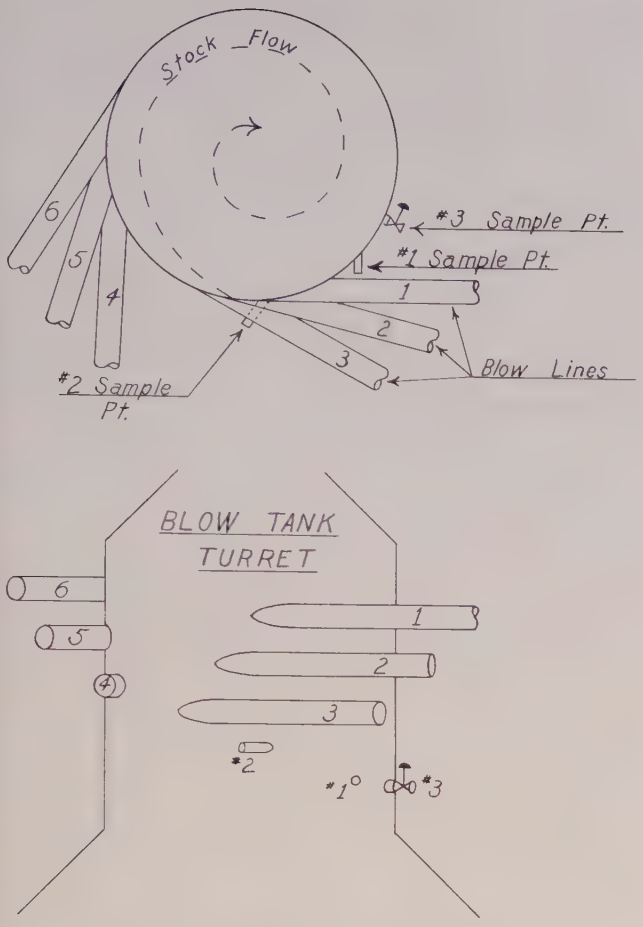

Fig. 1. Blow sampling system—sample points

moisture, variation in mixture of wood species, and fluctuation of the volume of knots to be recooked. Prior to installing our blow tank sampler, our method of sampling the brown stock off no. 4 brown washer did not give us a PBC and viscosity on a cook until two or three more had been blown. Furthermore, it was difficult to be sure of the time when a specific cook was on no. 4 washer. Any hang-up in the blow tank changed the stock through-time.

ADVANTAGES OF A SAMPLER

The automatic blow tank sampler we now have in operation gives us a sample of the cook, screened and ready for PBC and viscosity tests, about 3 min. after the cook has blown. Some of the advantages of this system are:

1. PBC and viscosity can be obtained in time to make adjustments on the next cook.
2. There is no uncertainty about which cook is being sampled, as the stock is sampled as it blows into the turret of the blow tank.
3. The cook is sampled intermittently all through the blow, and the tests are run on this composite sample. This gives accurate test values representing the average of the entire cook. A grab sample by our previous method could give very misleading test values if the cook was not uniform throughout.
4. Hang-ups or blending in the stock system between the blow tank and no. 4 washer cannot give samples on the wrong cook, as they could in the past.
5. This sampler makes it possible to test cooks for uniformity. In the past, we had no way of determining whether the chips were cooked the same in all parts of the digester. Now, however, we can sample any or all parts of a cook and determine the characteristics of each sample.

DEVELOPMENT WORK

The oft-expressed—but up till now frustrated—desire of both production and technical personnel to obtain a sample of a kraft cook as soon as it was blown, without the expenditure of any manpower and very little money, seemed difficult to attain. While neither assigned to such a project nor thinking about it, a means to accomplish this suggested itself.

Listening to the rush of stock entering the blow tank turret through a tangential blow line suggested the solution. Why not use the speed of the stock spinning around inside the blow tank turret to throw a sample back out?

No. 1 Sampler

To test this theory with a minimum of effort, an existing fitting was used. There was a 3-in. pipe coupling welded at a 45° angle near the bottom of the turret (see Fig. 1). Between blows, the plug in the end was unscrewed and a valve was attached. The valve was opened during the next blow, but nothing came out.

The valve was removed and the coupling was found to be plugged with stock. It apparently had plugged before the valve was opened. To improve upon it, an 8-in. length of $2^1/_2$-in. pipe, to one end of which had been welded a 30° elbow, was inserted, elbow-first, into the 3-in. pipe coupling. During the next blow, stock shot out in copious quantities at high speed and plastered the near side of the digester building. This made a mess, but proved that the theory was workable.

No. 2 Sampler

The 3-in. coupling could not be used permanently, as it is used to support planks inside the turret during maintenance work. Because of the location of the walk around the turret and the position of the blow lines, it also was difficult to get at. It was decided to weld another coupling to the turret in a more accessible position. A spot was chosen which was already serviced by the existing walkway, and not behind the blow lines (see Fig. 1). It had the disadvantages

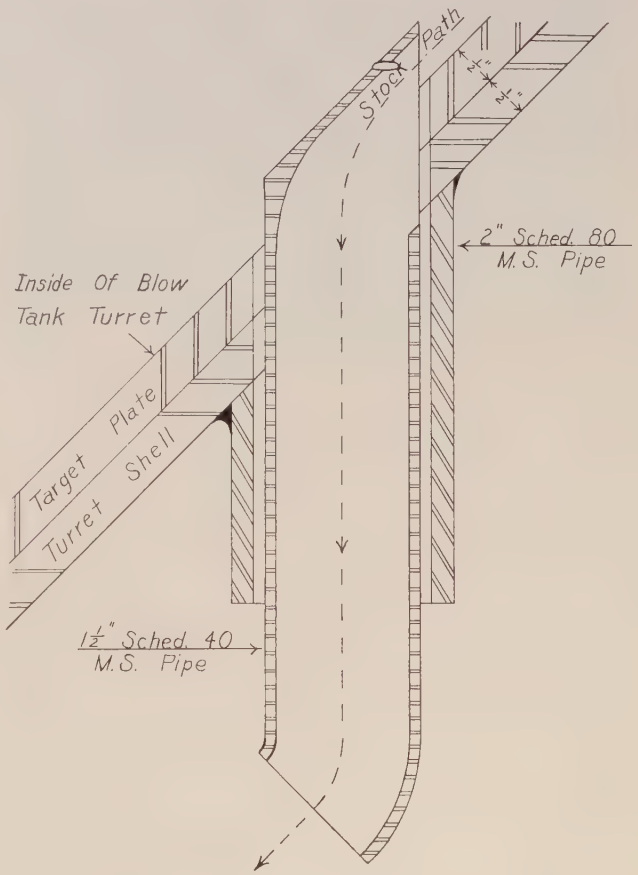

Fig. 2. Blow sampler no. 2

of being further around the turret from the blow line entries, and was higher than the 3-in. coupling (so a sample bucket could be placed under it). However, it was found that stock still discharged at this no. 2 sample point during the first 80 to 90% of a blow.

The no. 2 connection was made of a short piece of 2-in., schedule 80 pipe. Schedule 80 pipe was used because its bore will just pass a $1^1/_2$-in. pipe, which was used to build the sampler (see Fig. 2). The sampler was made by welding a 30° elbow to a piece of $1^1/_2$-in. pipe. Then, the pipe was chucked in a lathe and all protruding parts of the elbow were turned to the pipe outside diameter. Next, the outside of the elbow was built up with welding rod, so that the end could be ground off at a 45° angle and form a flat plane. When the sampler is in the retracted—no sample—position, this 45° plane becomes part of the target plate surface on the inside of the turret, filling the sample hole flush and leaving no holes or projections for stock hang-up.

It was planned to work this sampler by pushing it in for a sample and pulling it back flush with the inside to stop sampling. It was found that when the sample opening was fully exposed it sampled much too rapidly. When the sampler protruded just enough to give the desired sample rate, it plugged occasionally, usually with a knot. The solution to this proved to be very simple. It was found that if the sampler were rotated about 60° counter-clockwise at the same time it was pushed in slightly, it still ejected stock, but the plugging was eliminated.

To make the action more uniform, a camming device was attached. This was accomplished by bolting a split collar to the no. 2 connection. This collar extended beyond the end of the 2-in. connection and had a slot cut at an angle in one side. A short stud was welded to the $1^1/_2$-in. sampler, so placed that when the sampler was rotated clockwise until the stud hit the end of the slot, the sampler was in the "no sample" position. Rotating the sampler counter-clockwise started sampling; the more it was rotated, the faster the sampling rate. The stud served the second purpose of holding the sampler in place, so it could not blow out of the connection.

A rod was welded to the side of the sampler near the outside end, to be used for rotating it. A 30° elbow was welded to the external end to deflect stock into a bucket. A pan with a drain was put under the sampler to catch excess stock—which was flushed away with a hose.

This no. 2 sampler is effective, can be used intermittently or continuously during a blow, and is quite inexpensive. It would be a good one to install if one wishes to sample an occasional cook, run tests on cook uniformity, or even can be used for regular cooking control samples if a man is available to operate it. For not too great an additional cost, a timer and air cylinder could be attached for automatic operation.

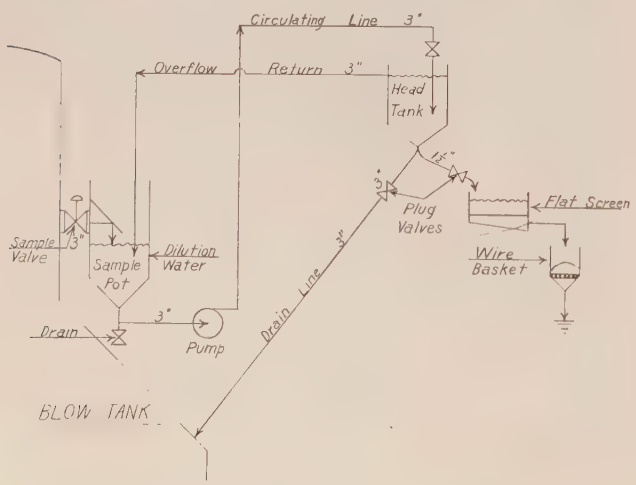

Fig. 3. Blow sampling system no. 3 flow diagram

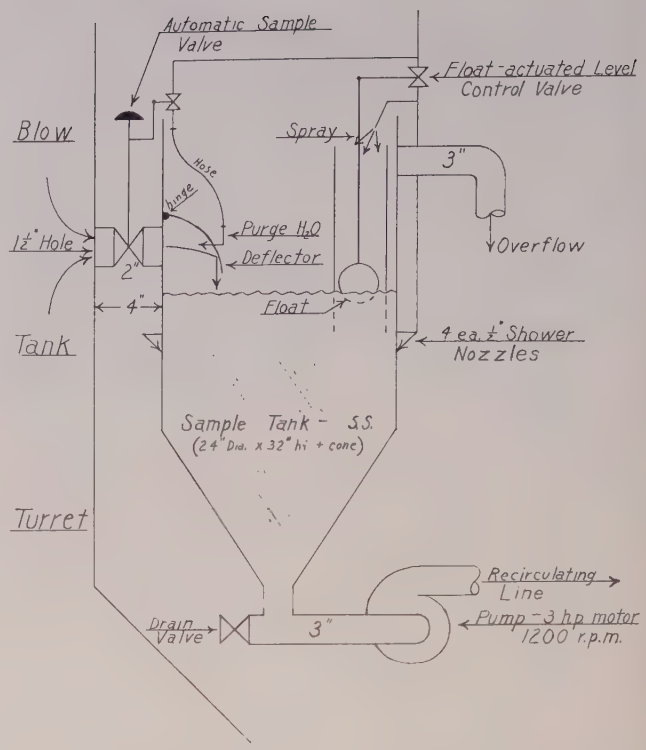

Fig. 4. Blow sampling system no. 3—sample tank section

The principal disadvantages to sampler no. 2 are:

1. It will plug occasionally.
2. If operated manually, the operator is in an exposed position should the blow tank safety valve above him let go—as it does now and then.
3. An operator has to walk a total of about 40 ft. to the sampler and back to get the sample, plus spend several minutes diluting the stock and screening it.

No. 3 Sampler—General Description

It was decided to build a completely automatic sampler in an attempt to eliminate the disadvantages of the no. 2 sampler. A generalized description follows, after which a detailed description of the various units in the sampler will be presented.

Number 3 sampler operates as follows (see Fig. 3): when the cook pushes any blow valve button, the sampler is activated. Stock is ejected intermittently through the sample valve into the sample tank. It mixes with the water in the tank and is pumped to the head tank on the digester floor. The head tank overflows back to the sample tank. This keeps the stock well mixed, and, at the end of a blow, the head tank has circulating through it a composite sample of the cook blown, at the right consistency for screening on the laboratory flat screen mounted below it.

At the end of a blow, the timer stops operating the sample valve. The operator starts the laboratory flat screen and opens the valve admitting stock from the head tank to the flat screen. The screened stock collects in a wire basket. In a minute or two, there is sufficient stock for the tests to be run. The operator then stops the flat screen and opens the drain valve. This drains the head tank into the blow tank. This stops the overflow from the head tank, which has been returning to the sample tank. As the pump is still pumping out of the sample tank, this level drops, opening the flow of fresh water through the dilution nozzles. The stock is pumped out of the sample tank in about a minute and is replaced by fresh water.

The operator checks the head tank, sees clear water coming from the sample tank, and closes the drain valve. The head tank fills with fresh water from the sample tank and starts to overflow. The system reaches equilibrium when the sample tank reaches its level setting, and the dilution nozzles shut off. It takes about two minutes from the time the drain valve is opened until equilibrium is reached. The system is now ready to sample another blow—about 5 min. after the end of the last blow.

No. 3 Sampler—Details

From observing no. 2 sampler in operation, it seemed probable that the slight pressure in the blow tank during a blow would force stock through a hole in the shell without using a scooping device. This proved to be true.

Number 3 sampler is built as follows (see Figs. 3 and 4). A thin, 2-in. wafer valve is attached directly to the blow tank turret over a 2-in. hole in same. This valve is operated by an air cylinder actuated by a flexipulse timer which has been set for the desired sampling time and frequency. When this valve opens, it also opens a water purge valve. This water is in a $^1/_8$-in. high pressure stream which shoots through the stock valve and into the blow tank. This prevents the stock valve from plugging but does not prevent the stock from blowing out the hole. The 2-in. hole in the turret was later reduced to a 1-in. hole, to keep back large knots which sometimes plugged the pump.

A stainless steel tank measuring 24 in. diam. and 32 in. in height (plus conical bottom) is coupled to the other face of the wafer stock valve. A deflector is fastened inside the tank to deflect the stock stream downward. This deflector is hinged so it can be swung upward out of the way. If the stock valve should plug, this makes clearing it very simple.

The sample tank is equipped with a float-operated level control valve. When the level in the tank drops, this valve supplies water to four $^1/_2$-in. water nozzles mounted tangentially on the tank to produce a swirling action to help mix the stock and the water. An overflow line is provided, in case the level control fails to function.

A 3-in. line runs from the bottom of the sample tank through a pump to the head tank. The first pump used gave us a lot of trouble with plugging. It was finally determined that this was caused at the neckdown to 2-in. discharge. A pump with 3-in. connections was substituted, and this works fine. This was an old Worthington, spare green liquor pump rated at 175 g.p.m. at 60-ft. head at 1800 r.p.m. This was more circulation than needed, so a smaller, 3-hp., 1200 r.p.m. motor was used.

The stainless steel head tank measures 24 in. diam. by 24 in. in height (plus conical bottom). Hand-lever-operated wafer valves were used on the drain line and on the stock line to the flat screen. These have proved difficult to operate, and the drain valve admits gases from the blow tank. Lever-operated ball valves might be more satisfactory.

The laboratory flat screen is manufactured by Valley Iron Works. It operates off a timer which automatically shuts it off after a pre-set screening time.

It was found that a great deal of foam developed during the sampling cycle. This is lessened by having the circulating lines discharge below the surface in the head tank and the sample tank. About 100 ml. of Nopco 1419-L antifoam agent added to the head tank before each blow eliminates the rest of the foam. A barrel of 1419-L is kept beside the head tank, with a plastic hand pump in the barrel and a tube from the pump to the head tank. One stroke of the pump delivers the required amount.

A rough cost estimate of no. 3 sampler is given below. This cost can be reduced by using a pump and motor already on hand and by fabricating your own tanks from scrap stainless steel pipe.

Pump	$ 400.00
Motor	100.00
Tanks	250.00
Valves	200.00
Pipe	50.00
Controls	100.00
Labor	600.00
Total	$1700.00

Due to lack of space in the area already accessible from the existing walkway, no. 3 sampler had to be located on the other side of the blow lines (see Fig. 1) and a ladder built over the blow lines, plus additional walkway. This location was nearer the blow line entries and was lower, which gave us better sampling.

It was found that PBC's run on stock from the blow sampler were about 0.8 point higher than PBC's off no. 4 brown washer. This is attributed to additional cooking taking place in the blow tank. The cooking specifications were raised 1.0 PBC, which took care of this problem.

CONCLUSION

Two usable blow sampling systems have been described. Number 2 costs very little, but requires some manpower to operate. Number 3 costs an appreciable amount, but requires less manpower and is completely safe. Either system can be used to get a composite sample of a cook

Presented at the meeting of the Pacific Section of TAPPI, held in Tacoma, Wash., Jan. 17, 1961.

The author wishes to gratefully acknowledge the considerable assistance of George Hansen, technical director, in designing the no. 3 automatic sampler; and Jack Murray, project chemical engineer, in working some of the "bugs" out of the system.

Black Cloth Dust Check on Coated Paper

R. A. Watt

A test was developed for measuring coating dust on coated paper at the paper machine. The test is performed by dragging a weighted black cloth or so-called dust rig on the moving coated web for a specified time. The weighted black cloth abrades the surface and the coating dust rubbed off is measured against dust number standards. Normal dust number ranges have been established for each coated grade which are guides for the coating process. The black cloth also detects loose coating particles and it was through the use of black cloth checks that the major cause of loose coating particles was pinpointed and virtually eliminated. The development, designing, and testing of the dust rig are discussed. Many mechanical variables were investigated and safety factors were also considered. The black cloth dust check has been established as a routine test on coated paper and has been an aid in the study and improvement of coated grades.

The technique of passing a black cloth over a single sheet of coated paper has often been used at West Linn to check for loose coating dust or foreign material. The test is made by folding a black cloth around a blackboard eraser or by holding the cloth in the hand and pressing it lightly over the sheet. The loose particles picked up in this manner are easily seen against the black background, and can be studied for identification. This hand wipe test served as the basis of the "black cloth dust check on coated paper."

The black cloth dust check that was designed gave an objective means for quickly detecting and measuring coating dust at the paper machine. Briefly, the test is made by dragging a weighted black cloth or so-called dust rig on the moving coated web. The dust rig is held easily in one hand by the paper tester and lowered onto the paper web. In the other hand the tester holds a stopwatch and times the test, based on machine speed, so that the black cloth passes over

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250 lineal ft. of paper during the test. At present the dust test is made on a routine basis on all our offset coated grades, and some of our letterpress grades. Dust standards have been established and each test black cloth is graded and given a dust number. The dust standards are numbered 1 through 10. The standards are actually black cloth dust checks arranged in order of increasing dust level. The dust number is the measure of chalkiness or powdery coating that is rubbed off the coated sheet during the test. A dust number of 1 indicates no rub off, a dust number of 10 indicates excessive rub off. The fact that the coating rubs off might seem alarming but this is a normal phenomenon resulting from abrading the coated surface with the weighted black cloth. Certainly coating can be rubbed off any coated sheet if the surface is abraded. Interestingly enough, definite dust number ranges have been established for each grade, which indicate normal coating condition. Variations out of the established ranges, however, would be considered not normal and would be immediately investigated. In this way machine operators use the dust numbers as a guide to compare the coating process from day to day and from run to run.

With the dust numbers we have made a few trials where changes in coating formulation have been made. In one trial, a pigment was substituted for our regular titanium dioxide brightening pigment. A definite increase in dust number was noted on the black cloths and after resuming the use of our regular pigment the dust number returned to normal.

The black cloth dust check has also been invaluable for detecting *loose* coating dust or coating flakes. Coating flakes are quite different from the powdery material that can be rubbed off a coated sheet. Coating flakes are small dried pieces of coating embedded in the coated surface of the sheet. On the black cloth dust check they appear as particles about the size of a head of a pin. In contrast to the dust numbers which are used as guides, coating flakes are very objectionable and are cause for rejection of paper. In our routine testing, paper testers reject paper based on our black cloth check when coating flakes are detected. However, it was through the use of black cloth checks that the major cause for coating flakes was pinpointed and virtually eliminated.

The situation which led to the development of the black cloth dust check on the machine came up about two years ago. We had started manufacturing a new coated grade for web offset printing and a comparison of this new grade with our regular offset sheet was needed. The situation demanded some sort of routine check on the coated sheet and the black cloth appeared to be the answer.

Several things had to be determined. What sort of an object was to be used to make the dust check? What point in the process should the test be made and what were the variables involved in such a test? In the designing phase, initial tests were made by holding a black cloth wrapped around an eraser on the coated web. Then we tried an eraser nailed at the end of a 4-ft. 2 × 2 with paper clips nailed above the eraser to hold the black cloth. This dust rig took both hands to manage as the rig had a tendency to tip. About the first time the rig tipped and broke the web down we were ready to change the design. Many other designs were tried but proved too awkward and as well two men were needed for the test—one to hold the dust rig and one to hold the stopwatch. Before arriving at the final design we had also experimented with different kinds and colors of cloth. Corduroy, muslin, velveteen, and percale in black and green were all tried. Black percale handled easily and accented the dust pick up best, and was our choice.

The dust rig finally designed, took one man for the test and many defects and variables in previous designs were eliminated. Briefly, the dust rig is constructed from a 6 × 10-in. piece of wool machine felt, on one end of which is rivited four $^1/_4$-in. thick iron bars. The bars are 1 in. wide and 6 in. long and act as weights to hold the black cloth under uniform pressure. On the other end is a wooden block to which the handle and paper clips are attached. Each cloth is fully identified including dust number, and is filed away chronologically and can be later referred to for study.

In determining the point in the process at which the dust check was to be made the variables involved as well as the design of the dust rig had to be considered. Dust checks were made at the machine, at the machine winder, at the supercalender, and at the supercalender winder. Speed of the moving web, pressure applied on the black cloth during the test, finish of the sheet and the amount of paper checked all proved to affect the test markedly. On the winders, for example, doubling the speed more than doubled the chalkiness rubbed off on the black cloths. Varying pressure on the dust rig had an even greater effect. In checks on the effect of finish, the supercalendered sheet showed far less rub-off than the unsupercalendered sheet. In studying the amount of paper to be checked, at a given web speed, the amount of dust pick up varied almost directly with time. However, at intervals of a minute or more the relationship didn't hold as the cloths began to fill and glaze over. A check of 250 lineal ft. appeared most practical and would give a test check of from 10 to 20 sec. depending on web speed. The mechanical variables discussed here are only part of the ones investigated. In addition to the mechanical features, safety factors in making the test also had to be considered. Also, operators wanted a quick check so they could be informed immediately of a machine condition. A dust check directly at the machine was the answer, and appeared most practical.

The paper tester makes the wire side dust check at the paper machine reel using a walk across test. That is, the test is started at the front of the machine and during the time required for the check the tester walks across the width of the reel, holding the dust rig on top of the reel in test position. The test is timed and as a safety factor the check is made when the reel diameter has built up considerably. One design advantage of the dust rig is that it follows the curve of the reel, and the separate bar weights keep pressure equally distributed on the black cloth.

The check on the top side of the sheet which is made at the front side of the machine just before the reel. Here the tester must exercise caution as the sheet is unsupported. In contrast to the walk across test on the wire side, only the front edge of the sheet is checked on the top side.

In developing the black cloth dust check inventiveness and considerable experimentation have transposed the simple black cloth check on a single sheet of coated paper to an on machine check where half a mile of coated paper can be checked easily and quickly. The black cloth dust check has been an invaluable addition to our coating operation and its use as a routine paper test on coated paper will be continued. It has been an aid in the study and improvement of coated grades and it stands as a watch dog to coated sheet quality.

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Twelfth Coating Conference

TAPPI

Statler-Hilton Hotel, Buffalo, N. Y.

May 8–10, 1961

The Skid Resistance Tester—An Instrument for Measuring Surface Resistance to Slip on Paper and Paperboard

Albert J. Beauchamp

An instrument has been developed for measuring the slip resistance of paper and paperboard using the principle of the inclined plane. The instrument features rapid testing and reliability of results.

Most of us are aware of the critical demands of the present-day consumers of paper and paper products. Competitively, our testing programs have to be rigid, thorough, unmistakably simple, and yet with the utmost elimination of human error.

In order to meet the demands in the development of new grades and physical properties of existing grades of paper paperboard, it has become necessary to seek out new testing instruments to evaluate these properties, or if not available, to develop devices to do these jobs.

The evolvement of the skid resistance tester* came about as a direct result of this. In the Camas Div. bag plant, a problem arose in the manufacture of multiwall bags for packaging building insulation materials. These materials, being very lightweight and bulky in nature, posed a problem for the distributor and consumer in shipment handling. The top tiers of a load would slip easily from a fast stop or bump in storage or in transit.

Some time ago, a number of suppliers developed additives for either paper machine or bag machine application to increase the resistance to slippage. These additives, which are colloidal silica compounds, have been used at Camas with good success. One such supplier issued a bulletin displaying their evaluation of this material, and also included a schematic illustration of a laboratory apparatus to test the nonslip properties when applied to paper and paperboard.

The principle of the inclined plane has been in use for countless centuries as a means of doing work by use of leverage. Its application here, however, is somewhat different. When used in this manner, this is one of the simplest and most efficient testing devices because the usual troublesome variables in friction from moving parts are not present. The two surfaces of the paper or paperboard to be tested are opposed to each other under given loading. This then becomes a measure of release to static friction because of the paper's own inherent qualities.

Figure 1 is the schematic drawing as shown in the bulletin. The inclined plane is pivoted at this point. The quadrant scale is calibrated in degrees relative to the base and the pivot point. Samples to be tested are placed and fastened on the plane and the loading block with the slip resistant surfaces facing each other. The motor is coupled to the gear box, and with the given pulley size, raises the plane at a rate of 2° per sec. As the inclined plane raises, a critical point is reached at which gravity overcomes the slip resistance of the two samples and the block begins to slide. The end point of the test is taken at the lowest whole degree when the first perceptible movement of the loading block is observed.

Albert J. Beauchamp, Crown Zellerbach Corp., Camas, Wash.
* Patent applied for.

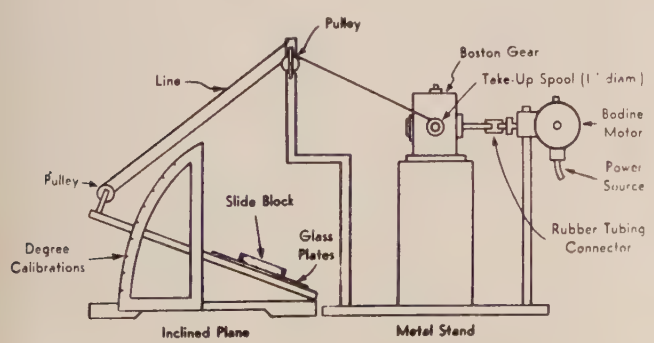

Fig. 1. Testing for skid resistance (slide angle apparatus)

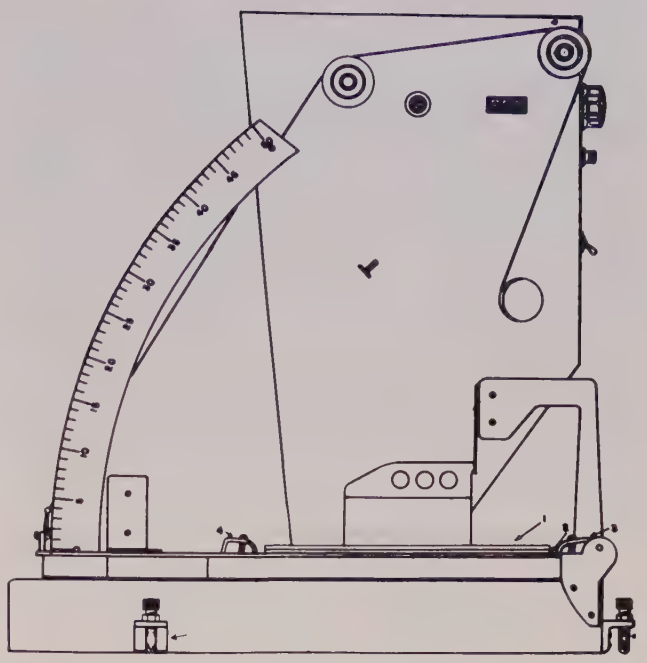

Fig. 2. Skid resistance tester

In the development of our skid resistance tester, we have incorporated this same principle but have modified the instrument. We could see the need for an instrument that could easily be carried from one testing point to another, and therefore, we have reduced the overall size to a very compact unit. Also, we could visualize errors in testing due to differences in the reaction time between individuals when observing the initial slip of the block, and at the same time observing the scale reading. Therefore, our instrument was built to be semiautomatic in this respect.

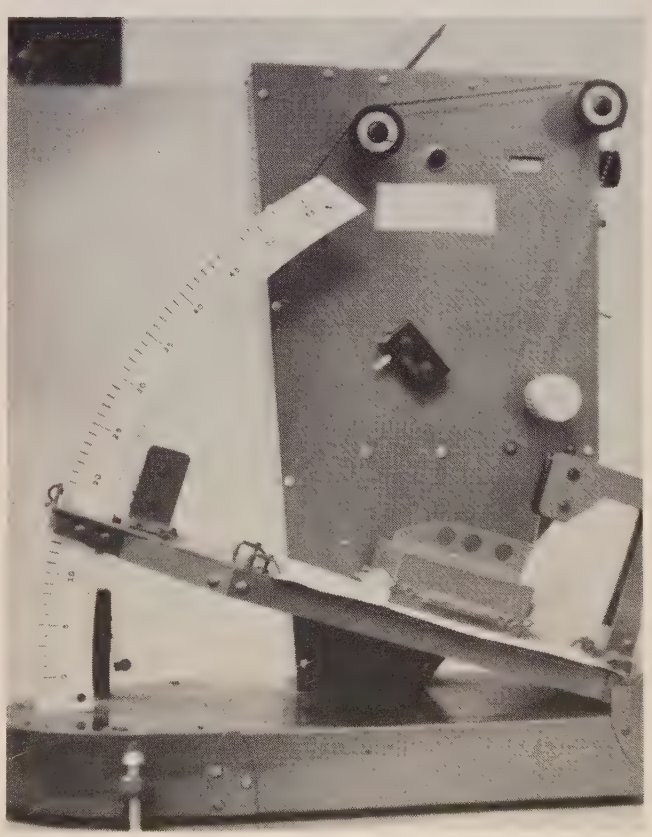

Fig. 3

Figure 2 slide shows a line drawing of our skid resistance tester. You can see that we still have the basic principles of the plane and the quadrant scale. We have incorporated a gear motor through the use of the pulley and bead chain which pulls the plane at the same rate of travel as that of the apparatus shown in Fig. 1. As the plane rises, an electrical impulse is transmitted to the electromagnetic counter which records the degrees of the quadrant scale. At the point at which the block initially slides, a switch is tripped which reverses the motor and takes the electromagnetic counter out of circuit. The plane then automatically returns to 0° The maximum angle to whicht he plane rose is retained on the counter until such time as the counter is manually reset to 0°.

We have had considerable experience using this instrument, (Fig. 3) not only on multiwall bag grades, but also on other grades whose surface slip properties are important. The results show that the instrument is capable of a high degree of reproducibility and is easy and convenient to use.

Presented at the meeting of the Pacific Section of TAPPI, held in Tacoma Wash., Jan. 17, 1961.

Curing Hand Sheets by Far Infrared Radiation

Bayard L. Carlson

The use of a far infrared radiant panel for curing laboratory handsheets at the off-machine condition overcomes the inherent disadvantages of circulating air ovens. Resulting cure is more uniform within individual sheets and between sheets in a set.

Originally, American-Marietta obtained an equivalent off-machine cure for handsheets through the hot plate procedure in which the sheet was given a 1 min. contact at 110°C. This method was later replaced by oven drying which gave test results showing that sheets could be cured for 4 min. at 105°C. Off-machine results were similar to those obtained from the former procedure. In addition, variations from sheet to sheet were found to be slightly less than similar variations obtained from the hot plate procedure. Thus, the drying oven method was adopted since it was determined that curing conditions at the lower temperature and longer cure time would reduce variations between experiments.

Later, an effort was made to improve the existing test procedure further. Data indicated that variations in test results developed from the amount of heat treatment or "cure" the handsheets received prior to testing. Some disadvantages of the oven technique were determined as follows: (1) oven cooling results when the door is opened to put in the handsheets, and (2) uneven heat distribution and air circulation in the oven.

Thus followed an investigation of the use of far infrared radiant panels. It was felt since radiant energy developed from parallel rays, having an average wavelength of 5 μ and reflected evenly, there would be high efficiency. In addition, there would be no overlapping circles of heat and no uneven spots as a result of hot and cold areas; also drying and curing by this method would eliminate high heat on the surface, thus preventing any damage to surface fibers. As a result, an infrared heat panel was acquired by the American-Marietta laboratories.

APPARATUS

The acquired infrared heat source is a Pyrex brand, PE 60 radiant panel, Corning Glass Works, Catalog No. 585643, 1300 watts, 115 v. a.c., $11^5/_8$ by $11^5/_8$-in. heating area. The panel is mounted in an open front aluminum box with shelf positions 3 and 5 in. from the panel.

Bayard L. Carlson, Product Manager—Paper Industry, Adhesive, Resin & Chemical Div., American-Marietta Co., Seattle, Wash.

The radiant energy from the panel is controlled by an "input controller" graduated from 0–100. This is manufactured by the Automatic Temperature Control Co., Inc., Philadelphia 44, Pa. Type J4A, Serial GP17, 115 v., 60 cycle, 25 amp.

The controller setting determines the per cent of the time that the electrical circuit is closed to the radiating element, based on a 1-min. cycle. This apparatus has been modified by installing a pilot light on the input controller to show when the circuit opens and closes. A sheetmetal shield covers the top 3 in. of the front opening. A sheetmetal holder for the handsheets has been constructed with a $6^1/_2$ in. diam. hole. This holder rests on the shelf supports and centers the sheet in the infrared field.

PROCEDURE AND DATA

To study the fluctuations in temperature during the on-off cycle of the panel, a thermocouple was placed between two sheets of kraft paper and placed in the infrared field at various input settings. A 1-hr. warmup period preceded evaluation at each setting.

At 20% input, 5 in. from the panel, the temperature versus time curve approximated a sine curve varying uniformly from 251 ± 2.5°F. on a 1 min. cycle. Similar curves occurred at 273 ± 2.5°F., with 25% input, and 370 ± 4°F. with 50% input. Thus, the maxima and minima vary about 1% from the average at all settings up to 50% input.

Uniformity of Cure

To study the uniformity of cure a number of 100% unbleached kraft handsheets was made with 1% urea-formaldehyde wet-strength addition level and air dried in the usual manner. Sheets were then cured at various input settings, 5 in. from the panel for 30 sec. After cutting, the test strips were assembled in their original position in the sheet and tested for wet tensile strength.

Table I. Wet Tensile Strength (lb./in.)

% Input	Average	Maxima	Minima	Range of readings
Control	5.04	5.65	4.55	1.10
10%	5.77	6.40	5.50	0.90
20%	5.93	6.50	5.30	1.20
25%	6.05	6.55	5.45	1.10
40%	7.96	8.80	7.60	1.20

The high and low readings were well distributed in the sheet and did not indicate any areas of greater cure. Thus, variations within the sheet are considered due almost entirely to sheet formation.

Comparison of Oven and Infrared Cure

A set of handsheets with 1% wet strength was made. Half were cured in a circulating air oven for 4 min. at 105°C. and the other half exposed to the infrared field for 30 sec. at 35% input at 5 in. distance. The sheet averages for each cure condition were as follows:

Table II. Tensile Strength (lb./in.)

	Infrared cure		Oven cure	
	Dry	Wet	Dry	Wet
	39.4	3.62	41.0	3.72
	42.4	4.19	39.2	3.86
	40.7	4.13	44.3	4.56
	41.0	3.89	41.3	5.25
	41.0	4.41	39.2	4.58
	39.6	4.36	42.6	4.54
	42.0	4.66	41.0	5.28
	42.0	4.78	44.2	5.57
	42.3	4.51	41.7	5.28
Average	41.2	4.28	41.6	4.78
Max.-min. range	4.0	1.16	5.1	1.85

Table II indicates a narrower range of variation between sheets cured by infrared than those cured in the oven. The scattering of values for handsheets cured by infrared closely approximates a normal distribution curve, while the data for the oven cured sheets show a relatively large number of low values, and the average is well below the mode.

Application

To simulate "off machine" cure it has been determined that an oven cure for 4 min. at 105°C. gives a wet-strength efficiency of 11 to 13% to 100% unbleached kraft handsheets of 50 lb. basis weight (25 × 40—500) to which 1% urea-formaldehyde wet-strength resin has been added at a pH of 4.5 with 2 N H_2SO_4.

It was found that a 30 sec. exposure to the infrared panel at a distance of 5 in. and an input of 30% gives "off machine" cure in the 11 to 13% wet-strength efficiency range. Sheets are inserted at the instant the pilot light goes on, thus insuring insertion at the same point in the heating cycle each time.

SUMMARY

We believe these data and our practical experience during the last four years indicate that application of infrared radiation to cure handsheets is a useful tool in order to simulate production off machine sheet curing.

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Presented at the meeting of the Pacific Section of TAPPI, held in Tacoma, Wash., Jan. 17, 1961.

The Function of Quality Control

James J. Whyte

One of the functions of quality control is the setting up of specifications followed by control to see that the specifications are met. These points are discussed briefly.

I AM happy to have been invited by the moderator, Harold Randles, to give a short talk on the function of quality control today. First, I do not want to set myself up as an expert, because I have only worked in this field for one year, which is the length of time that we have had the new quality control program at St. Regis-Tacoma. However, I would like to pass along, for what it is worth, my impression of the function of quality control.

What is quality control? If asked this question, I would have to answer that quality control, in the main, consists of two parts, namely making specifications and meeting specifications, but after a little thought, you have to change this a little because your company has to make a profit. So now the definition of quality control is the making and meeting of specifications so that the producer can show a profit. Now when we think we have the definition right, we have still forgotten one man—the consumer or the user of our product. So now we have the final definition which says quality control is making and meeting specifications on which the producer can make a profit and with which the consumer will be satisfied. So the first function of a quality control program is to set up these specifications. How are specifications set up? In general, I would say they were made up from these five main sources:

1. From past performances where we have made the grade before. The customer has accepted paper and you continue making the same thing over and over for him. The advantage is that this is the easiest method, in fact, John M. McEwen, of Everett, says this is like a cross-eyed cowboy who shoots the bullets and then draws a target around the bullet hole. The disadvantage is that you never know how far over the needed specifications you are, and thus you may be wasting time and chemicals.
2. From government specifications and freight specifications. We are all familiar with UUS 48C and other government regulations which are perhaps the most solid specifications that we have because it is absolutely mandatory that we meet these.
3. From customer specifications. These represent perhaps the least number of our specifications, because although a customer knows what he wants the paper to do for him he cannot translate this into specifications. Therefore, we must do this for him, but with companies merging and getting larger this source will grow in the future.
4. From the standard specification book which is made up in our central Quality Control Laboratory in Deferiet, N. Y. This is done because we wish to put out a standard product in all our mills, so that if at any time we would want to shift an order from one mill to another, the customer will get a standard product.
5. From the quality control group at our locality.

I would now like to explain further the work of this quality control group and how it operates. The group meets daily—five days a week—with Friday, Saturday, and Sunday production matters being taken care of on Monday. This meeting is in the morning, and so we start the day off being quality minded. The quality control group consists of the resident manager, who is chairman of the meeting and his staff: the assistant to the resident manager; the manufacturing superintendent, the paper mill superintendent, the pulp mill superintendent; the technical superintendent, and the assistant technical superintendent. Also the sales representatives who are responsible to the product vice-president-sales, and the quality control representative, who reports to the quality control manager in Deferiet, and who notes any action taken. So now you can see how each division of our operation is present to present his case when discussing specifications.

In setting up specifications, each department sees the problem from a different viewpoint, thus the resident manager and the manufacturing superintendent hold to the point that we cannot have certain specifications because they cost too much. The paper mill superintendent says if we could change the specifications slightly, he could get an extra 50 f.p.m. off the machine, thus getting more production for the day. The technical superintendent says there are too many specifications requiring tests and his testers cannot possibly keep up. The pulp mill superintendent says if we cook the stock harder we could get a better yield. The sales representatives say we must meet these specifications if you expect us to keep our customers. But, by a daily meeting of these people, strange as it may seem, we do come up with specifications and each one of the group had had his part in them. But in a close decision, I think we all know which way it will go.

After the decision is made, it is up to the quality control representative to get this information to the people who are making the paper, namely all people who attend the meeting plus the machine tender, back tender, and paper tester.

We distribute this information by means of a file card system. The front of these cards has a list of all the tests we do on the paper, with a spec column, a minimum column and a maximum column, and a "hold if under" column and a "hold if over" column. On the back of the card we list the customers who buy this grade and any comments sales or production wish to emphasize.

The second function of quality control is to see that the specifications are met. I think we will all agree that instrumentation is one of the most important factors when speaking of specifications being met, because of what use is a esult unless we know it is correct. So, to insure correct results it is the duty of the quality control representative to see that all tests are carried out correctly with correctly calibrated instruments. This is done both by the shift tester and by an instrument man whose duty it is to check the instruments by

J. J. WHYTE, St. Regis Paper Co., Tacoma, Wash.

a set check list. This instrumentation is set up and kept up by a central laboratory under the test method and instrument group. This group also clearly defines how each test is to be run, and how each instrument is to be checked, so you can be quite sure that your results will have a minimum of error due to instrument failure. The actual supervision of the testing is in charge of the technical department.

Now, what happens if we do not make the specifications which are deemed important? This paper is set aside, and after being rechecked it is discussed at the quality control meeting and there, the sales representative who acts as the customer's representative, decides whether this paper will be acceptable to his customer. If it isn't acceptable it still can be downgraded, or may even be sold as a different grade. These decisions come from the group with the resident manager, the manufacturing superintendent, and the sales representative making the actual decision. And it is then up to the quality control representative to see that their decisions are carried out, and to keep a record of the action taken.

In this we try to keep as concise as possible and just have two categories.

1. The paper with any test out of specifications, which may have been (a) culled, (b) converted to other grades, or (c) shipped.

2. The paper culled for roll defects, grade changes, and washup. Of course all of this is culled.

In keeping these totals we can keep score on how we are doing from month to month, and as time goes on we will develop a mean and in this way we will have a method of knowing where we stand.

It is the function of quality control to point out by actual observation little things which affect the quality a great deal and which might possibly be overlooked by a person doing the actual job.

The function of quality control is to have programs that workers like. We can do this by giving them the tools to inspect their own work, to correct errors by themselves, and by letting them, through guidance, experience the satisfaction of turning out a better product.

It is the function of quality control to substitute an objective search for causes of trouble in place of personal criticism and buck passing.

It is the function of quality control to develop a better understanding between each department so that there will be no repetition of work and yet there will be a unity of purpose.

The function of quality control is to implant in the minds of the workers that quality must be built into the product, right from its very beginning. By doing this, we will practically eliminate cull and off-quality. As one man puts it: "Profits equal the selling price—minus the cost—minus the off-quality." In the present market your competitors won't let you raise the selling price, the unions may not let you lower the costs, but nobody will stop you from cutting down on your cull and off-quality.

It is the function of quality control to develop our statistical knowledge so as to be of help to the operation and in this respect we have a central statistical group which is continually working on our problems.

The function of quality control is to reduce rather than increase inspection and make inspection more effective by using proper procedures and by sampling based on statistical developments.

Speaking of procedures based on statistical developments, I would like to show you a system which has been developed to measure accurately suppliers quality—so claims the user. In order to do this, they use the following formula:

$$SQR \text{ equals } 100 \text{ minus } \frac{\text{sum } Cidi}{\text{sum } ni} \text{ minus } \frac{20\ DL}{\sqrt{NL}}$$

where

SQR = Supplier quality report
Ci = the constant
$Ci = \dfrac{\text{sum } ni}{AQL}$
di = the number of items defective
ni = the sample size
DL = the lots rejected
NL = the lots inspected

where the AQL is the acceptable quality level and can be defined as the per cent defective allowed as a process average for the parts inspected upon receival. The AQL's are assigned over a range of 0 to 10% with the more critical characteristics receiving the lower AQL values.

The formula provides a rating of 100 to suppliers who submit material with no defects and lower ratings for those suppliers who submit material with defects. For example:

If the above supplier had submitted 25 lots, of which five were rejected due to 29 defects, the calculations would be as follows:

AQL	ni	di	Ci	$Cidi$	DL	NL
0.65	990	4	3100	12,400		
1.00	755	6	2000	12,000		
4.00	190	9	500	4,500		
6.50	65	10	310	3,100		
Totals	2000			32,000	5	25

$$SQR \text{ equals } 100 \text{ minus } \frac{\text{sum } Cidi}{\text{sum } ni} \text{ minus } \frac{20\ DL}{\sqrt{NL}}$$

$$SQR \text{ equals } 100 \text{ minus } \frac{32000}{2000} \text{ minus } \frac{20\ (5)}{\sqrt{25}} \text{ equals } 64$$

This is one of the methods, using IBM equipment, by which the quality of our products may be graded in the future. It will be the function of quality control to keep the company's average as high as possible. We could continue on with the functions of quality control, because they are never ending, but I hope we have hit upon the important ones.

In closing I would like to point out that if the most is made of the functions of quality control, we will reduce our off-quality and cull, thus raising our profits; we will improve our product, and thus give our sales department powerful ammunition in holding existing customers and getting new ones.

Presented at the meeting of the Pacific Section of TAPPI, held in Tacoma, Wash., Jan. 17, 1961.

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Mill located about ten miles northwest of Center Philadelphia in Montgomery County, Pennsylvania, in an area with a wide choice of desirable living conditions.

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(P1058-61)

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Immediate position open in Research and Development Department of absorbent specialty mill located in midwest. Prefer man with degree of chemistry and three years of paper mill experience. Knowledge of saturating papers and saturating resins desirable.

Write to **P1054-61, Tappi, 360 Lexington Ave., New York 17, N. Y.**

CHEMIST
or
CHEMICAL ENGINEER
WANTED

Graduate, with three to five years' experience in the pulp and paper industry, for an integrated bleach kraft pulp and specialty paper mill. Involves work in mill control and/or process control and development. Opportunity for a competent and ambitious man to advance to positions of greater responsibility. Excellent benefits and good starting salary. Please furnish complete particulars as to experience, education and reference to **P1075-61, Tappi, 360 Lexington Ave., New York 17, N. Y.**

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Molded Products

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(P1080–61)

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Excellent opportunity in new, modern research center in Cleveland, Ohio as Group Leader.

Must have experience in developing and evaluating resins for use in paper coatings, adhesives or related fields and be capable of directing group research and development projects.

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Kindly send résumé and salary requirements to:

Robert E. Lamalie
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HALOID XEROX INC.
P.O. Box 1540
Rochester 3, New York

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(P1082-61)

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QUALITY CONTROL

Rapidly expanding, office-equipment manufacturer has opening for highly qualified man as staff assistant to director of sensitized products Q.C.

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Responsible for monitoring and maintenance of basic calibration for Q.C. testing, development of improved test equipment and methods, coordination of Q.C. departmental tests with new-product specifications from research. Assist Q.C. director in development of policy pertaining to raw materials and process Q.C.

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We have opening for a Technical Superintendent to head up our Technical Services Department at our Naheola, Alabama operations. Operations consist of Bleached Kraft Pulp Mill, Bleached Specialties, Light Weight Paper and Boards, Tissue and Toweling Manufacture and Converting. Responsibilities include process engineering, quality control, statistical department, and administration of laboratory. Excellent opportunity.

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Industrial Relations Department
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A DIVISION OF AMERICAN CAN COMPANY
P. O. Box 315
Butler, Alabama

(P1084-51)

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(P1085-61)

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This is an excellent opportunity to use your initiative and creative ability in an atmosphere conducive to accomplishment.

Salary open. Age to 35.

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A dynamic, rapidly expanding manufacturer of photographic and xerographic products has outstanding growth opportunities for:

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B.S. in chemistry with 5 to 10 years' experiences in chemical industry. Sound background in organic and inorganic essential. Economic training should include quality control statistics and data processing. Responsible for development of raw material and vendor assurance programs for gelatin, selenium, and paper base for sensitized and xerographic products and auxiliary supplies. Will develop inventory and quality status importing and procurement policies; control release of raw materials to meet production schedules; operate complete department.

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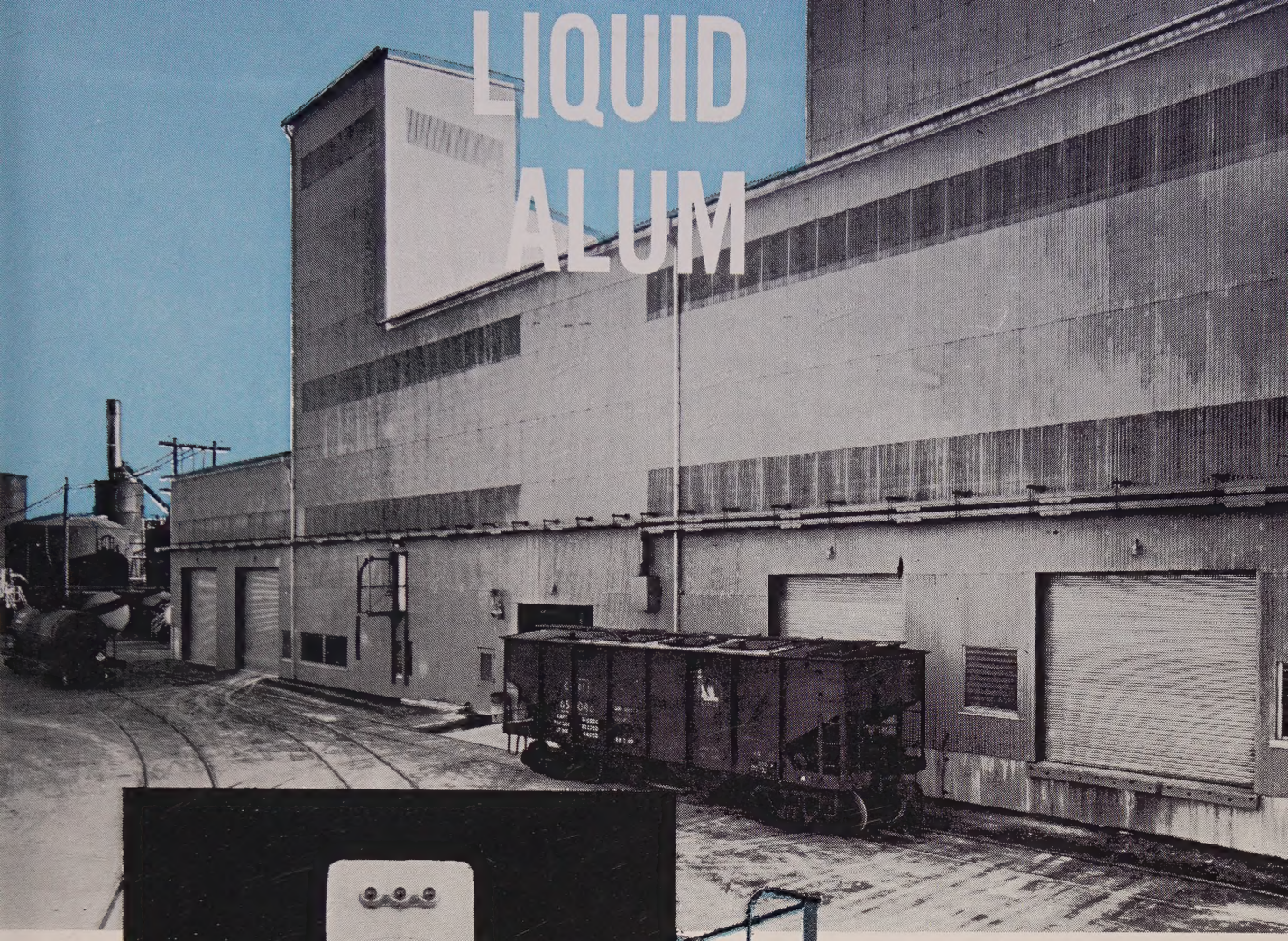

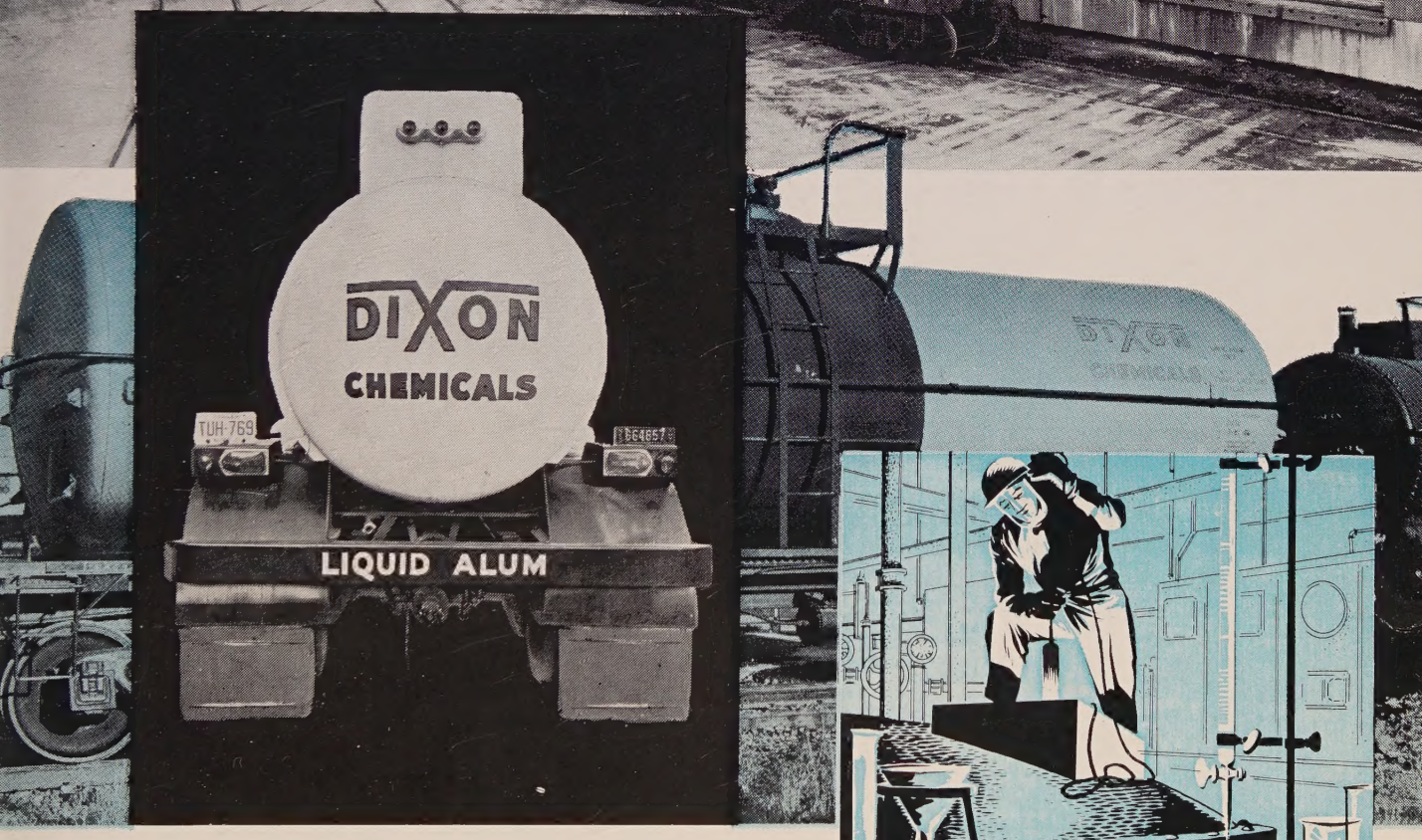

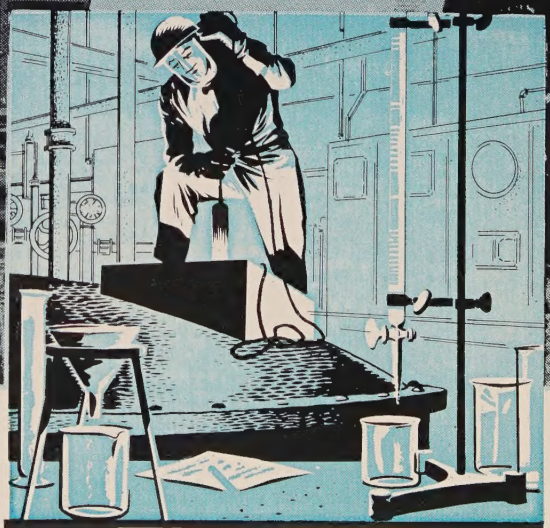

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